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DEPARTMENT OF THE INTERIOR—U. S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

WATER RESOURCES

OF

INDIANA AND OHIO

BY

FRANK LEVERETT

EXTRACT FROM THE EIGHTEENTH ANNUAL REPORT OF THE SURVEY, 1896-97
PART IV—HYDROGRAPHY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1897

THE WATER RESOURCES OF INDIANA AND OHIO.

BY

FRANK LEVERETT.

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WATER RESOURCES OF INDIANA AND OHIO.

By FRANK LEVERETT.

GENERAL STATEMENT.

The gathering of material concerning water resources contained in this paper has been carried on largely in connection with glacial studies which the writer has pursued under the direction of Prof. T. C. Chamberlin. These studies were begun in Indiana in 1887 and in Ohio in 1888, and have embraced about six field seasons. As a result of this connection with glacial studies the data are much fuller in the glaciated than in the unglaciated portions of these States.

The data collected on the underground waters are much more full in the Indiana than in the Ohio portion, and embrace not only the waters from wells obtained from glacial deposits, but also those from the rock formations. The underground waters of Ohio are to be discussed by Prof. Edward Orton in a paper for this Survey, hence only brief reference is made to them in the present discussion.

Since arrangements are being made by this Survey for a special investigation of water power in Indiana, and since the water power of Ohio has been discussed quite fully by Prof. Dwight Porter in the Tenth Census Report,[1] the subject receives but little attention in this paper.

A special circular letter making inquiries concerning city water supply was mailed to town officials, or others qualified to give information, in all towns of Indiana and Ohio having a population of 1,000 or more and to smaller towns which were known to have a waterworks system. The generous response to that letter makes it possible to present a somewhat full report upon this subject. It is taken to be a measure of the general deep interest in the publication of such statistics, and the writer wishes here to acknowledge great indebtedness to the large number of persons who have supplied information. Advance sheets of the Manual of American Waterworks for 1897, published by the Engineering News, have been furnished through the kindness of the editor, Mr. M. N. Baker, from which statistics concerning waterworks are rounded out and brought down to date. Proper credit is given in the tables of city

[1] Report on the water power of the Ohio River Basin and the Ohio State Canals, by Dwight Porter: Tenth Census of United States, 1880, Vol. XVII, pp. 429-504.

water supply for statistics thus obtained. The pains taken by Mr. Baker and his associates in collecting this body of statistics can be appreciated only by those who attempt similar work, and his kindness in thus cooperating places us under a debt of gratitude to him.

PHYSICAL FEATURES.

ALTITUDE.

The accompanying topographic map (Pl. XXXIII) presents 100-foot contours, which are based principally upon railway-survey altitudes. A large part of these data, which include not only stations, but also natural summits and beds of streams crossed by the railway lines, were collected by Mr. Henry Gannett, of this Survey, and arranged for his forthcoming revised edition of the Dictionary of Altitudes in the United States. Through Mr. Gannett's kindness the writer has been given free access to all such unpublished material as pertains to Indiana and Ohio. Some of the elevations were obtained from Capt. H. M. Chittenden's map accompanying his report on the canal routes between Lake Erie and the Ohio River.[1] A considerable number of elevations have been obtained from Professor Orton's list of altitudes in Ohio, published in Volume VI of the Ohio Geological Survey. For the outlining of the 800-foot contour in Monroe and Lawrence counties, Indiana, Mr. C. E. Siebenthal, of the Indiana survey, should receive credit. Where precise elevations are wanting use has been made of aneroid readings taken by the writer.[2] A general acquaintance with the topography of the region has also been of service in drawing the contour lines. The minor sinuosities of the contour lines must necessarily be neglected on a map of this scale. It is thought, however, that the variations in altitude are presented with a sufficient degree of approximation to represent fairly the general features.

The mean elevation of Indiana is estimated by Mr. Gannett, through a study of railway elevations and other published data, to be 700 feet above tide.[3] Mr. S. S. Gorby, formerly State geologist, who has a somewhat intimate personal acquaintance with the features of the State, estimates the average altitude to be 800 feet.[4] Nearly three-fourths of the State stands between 500 and 1,000 feet. Of the 35,910 square miles there are, according to Mr. Gannett's estimate, but 2,850 square miles above the 1,000-foot contour and but 4,700 square miles below the 500-foot contour. The highest land is found near the eastern boundary of the State, in southern Randolph and northern Wayne counties, where the altitude reaches about 1,250 feet above tide; it is

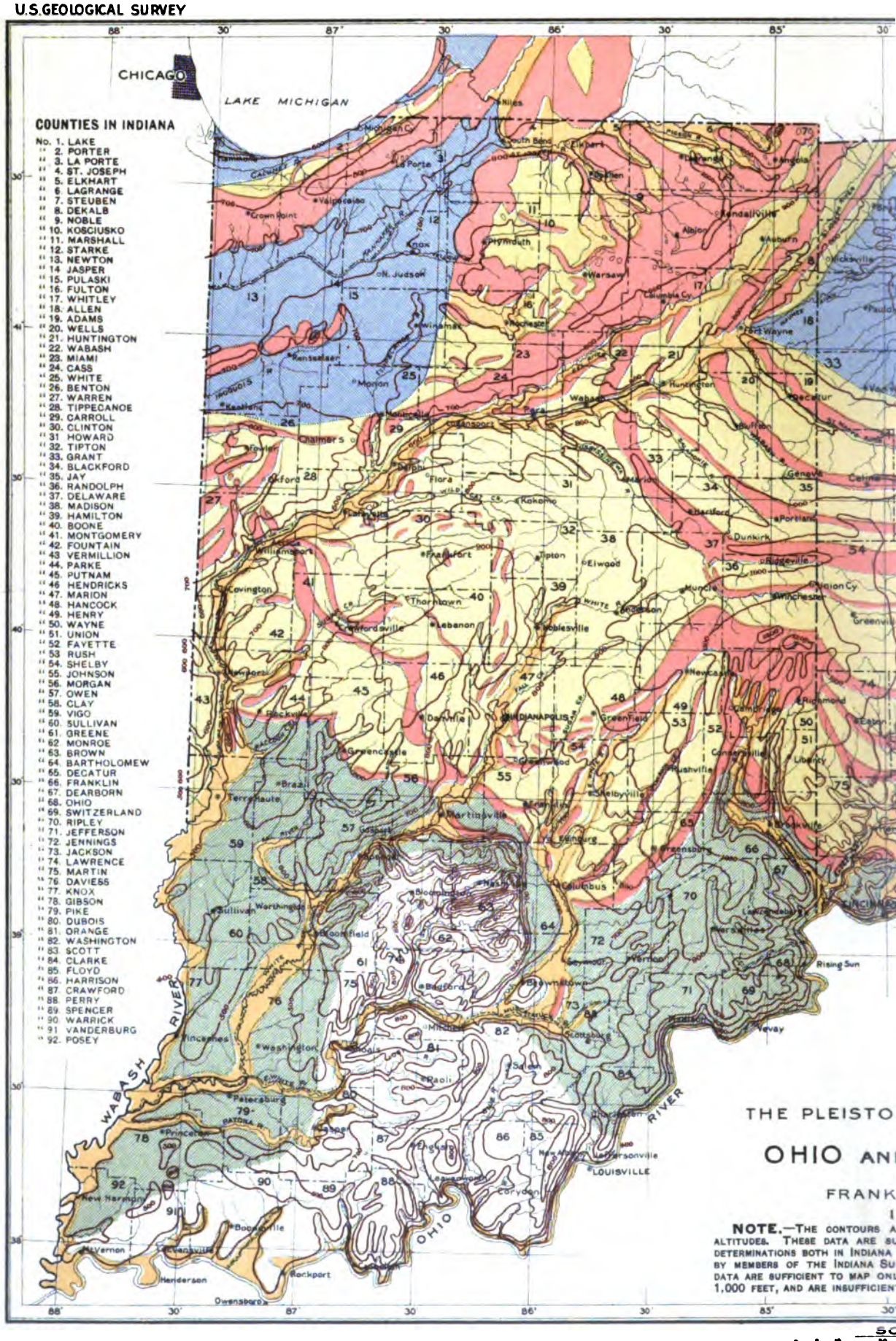
[1] Ex. Doc. No. 278, House of Representatives, Fifty-fourth Congress, first session, 1896.

[2] It should be noted that in the unglaciated portion the contouring is restricted mainly to the 1,000-foot line. The available data are too meager to justify the full contouring attempted in the glaciated portion. A part of the glaciated upland in northeastern Ohio is also defective in this respect.

[3] Thirteenth Ann. Rept. U. S. Geol. Survey, Part II, 1893, p. 289.

[4] Sixteenth Ann. Rept. Indiana Geol. Survey, 1891, p. 217.

U.S.GEOLOGICAL SURVEY



GLACIAL RIDGES

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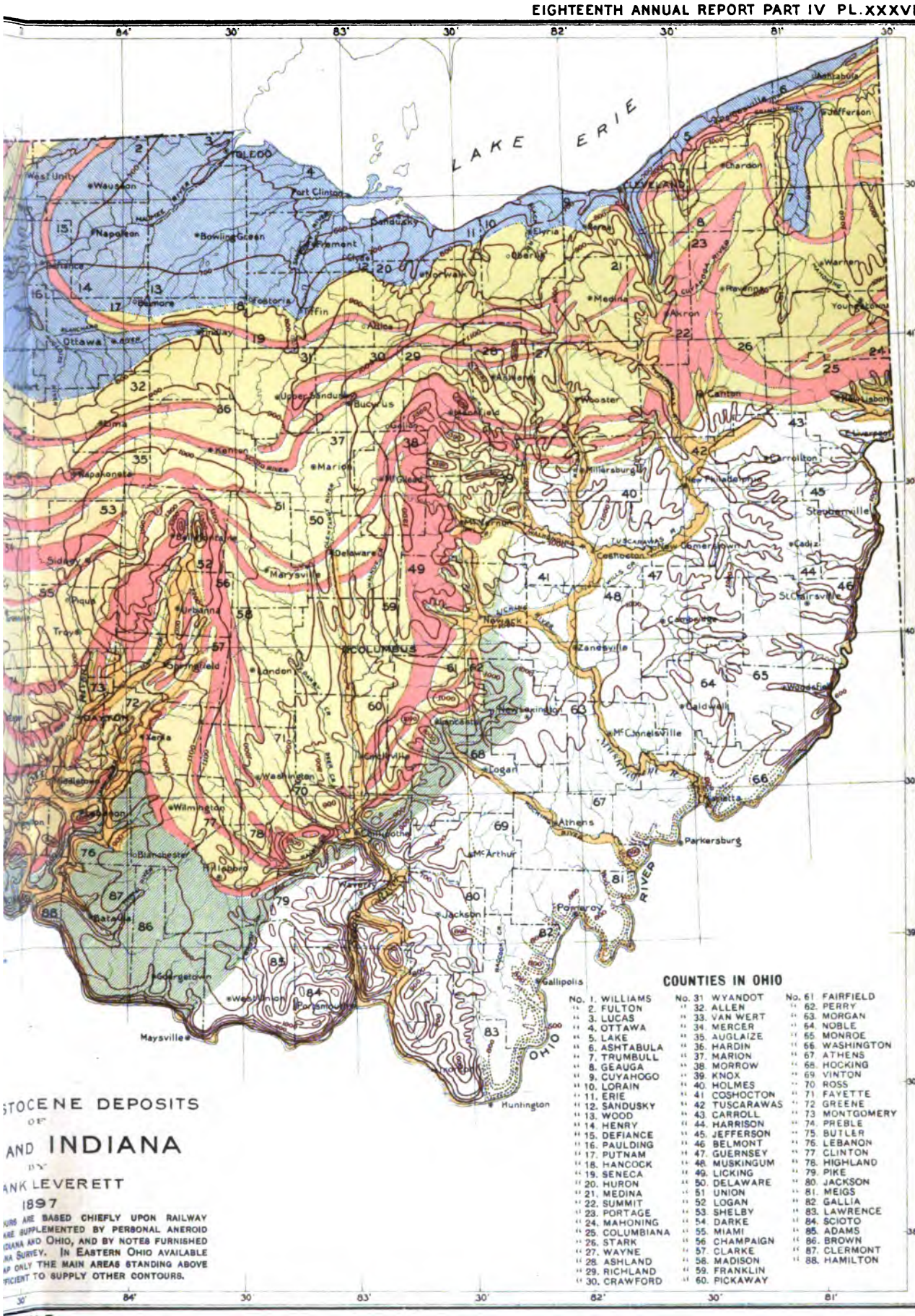

COUNTIES IN OHIO

No. 1. WILLIAMS	No. 31 WYANDOT	No. 61 FAIRFIELD
" 2. FULTON	" 32. ALLEN	" 62. PERRY
" 3. LUCAS	" 33. VAN WERT	" 63. MORGAN
" 4. OTTAWA	" 34. MERCER	" 64. NOBLE
" 5. LAKE	" 35. AUGLAIZE	" 65. MONROE
" 6. ASHTABULA	" 36. HARDIN	" 66. WASHINGTON
" 7. TRUMBULL	" 37. MARION	" 67. ATHENS
" 8. GEAUGA	" 38. MORROW	" 68. HOCKING
" 9. CUYAHOGO	" 39. KNOX	" 69. VINTON
" 10. LORAIN	" 40. HOLMES	" 70. ROSS
" 11. ERIE	" 41 COSHOCTON	" 71 FAYETTE
" 12. SANDUSKY	" 42 TUSCARAWAS	" 72 GREENE
" 13. WOOD	" 43. CARROLL	" 73 MONTGOMERY
" 14. HENRY	" 44. HARRISON	" 74. PREBLE
" 15. DEFIANCE	" 45. JEFFERSON	" 75. BUTLER
" 16. PAULDING	" 46 BELMONT	" 76. LEBANON
" 17. PUTNAM	" 47. GUERNSEY	" 77 CLINTON
" 18. HANCOCK	" 48. MUSKINGUM	" 78. HIGHLAND
" 19. SENECA	" 49. LICKING	" 79. PIKE
" 20. HURON	" 50. DELAWARE	" 80. JACKSON
" 21. MEDINA	" 51. UNION	" 81. MEIGS
" 22. SUMMIT	" 52 LOGAN	" 82. GALLIA
" 23. PORTAGE	" 53. SHELBY	" 83. LAWRENCE
" 24. MAHONING	" 54. DARKE	" 84. SCIOTO
" 25. COLUMBIANA	" 55. MIAMI	" 85. ADAMS
" 26. STARK	" 56 CHAMPAIGN	" 86. BROWN
" 27. WAYNE	" 57. CLARKE	" 87. CLERMONT
" 28. ASHLAND	" 58. MADISON	" 88. HAMILTON
" 29. RICHLAND	" 59. FRANKLIN	
" 30. CRAWFORD	" 60. PICKAWAY	

STOCENE DEPOSITS
OF
AND INDIANA
BY
ANK LEVERETT
1897

URS ARE BASED CHIEFLY UPON RAILWAY
ARE SUPPLEMENTED BY PERSONAL ANEROID
DIANA AND OHIO, AND BY NOTES FURNISHED
NA SURVEY. IN EASTERN OHIO AVAILABLE
AP ONLY THE MAIN AREAS STANDING ABOVE
FICIENT TO SUPPLY OTHER CONTOURS.

SCALE
20 10 0 20 30 40 50 MILES

J. OTTMANN LITH. CO. PUCK BLDG. N.Y.

ED TIL - VALLEY DRIFT AND ALLUVIUM — EXTINCT LAKES — UNGLACIATED

in the midst of the main area that rises above the 1,000-foot contour, as may be seen by reference to the map (Pl. XXXIII). A small area in the northeast corner of the State rises above 1,000 feet, and still smaller areas in Hendricks, Brown, and Washington counties, too small to be indicated on the map, also exceed 1,000 feet. The portion falling below 500 feet is confined to the southwestern corner and to valleys in the southern half of the State. The lowest elevation (at the mouth of Wabash River) is 311 feet above tide at low water of the stream.

The mean elevation of Ohio is estimated by Mr. Gannett, in the paper above cited, to be 850 feet, or about 150 feet greater than that of Indiana.[1] Only 460 of the 40,760 square miles in the State are estimated to fall below 500 feet, and this low part is confined to the Ohio Valley and the lower course of its tributaries, the lowest point being about 425 feet above tide. Less than one square mile stands above 1,500 feet. This is near Bellefontaine, in Logan County, in the west-central part, where one hillock reaches 1,540 feet and another 1,525 feet above tide. At least one-fourth of the State stands above 1,000 feet. This elevated part is largely in the eastern half, though it is estimated by the writer that nearly 4,000 square miles in the western half stands above 1,000 feet. Two-thirds, or possibly a larger part, of the State is between 500 and 1,000 feet above tide. The western half is lower than the eastern, because it includes the two most extensive lowlands of the State, one bordering the western end of Lake Erie, the other occupying the Scioto basin. Furthermore, the great elevation attained in Logan County, in western Ohio, is confined to a few square miles, there being very little territory in western Ohio standing above 1,200 feet. But in eastern Ohio there are extensive areas rising not only above 1,200 feet, but even above 1,300 feet.

RELIEFS.

Under this head the escarpments, ridges, or hills formed by variations in rate of disintegration of the rock strata are discussed. The broad arches due to uplift are also briefly considered. Morainic ridges, dunes, and other aggregations of Pleistocene age are not included.

Throughout the greater part of Indiana and in northwestern Ohio the glacial deposits are so heavy as to conceal the reliefs quite effectually and to reduce the surface to a somewhat smooth contour. Indeed, the morainic ridges constitute the principal features that would attract notice in the northern two-thirds of the region. The southern third of Indiana has largely escaped glaciation; the southern part of western Ohio has been less heavily covered than the northern, and much of the

[1] The great extent of elevated tracts in eastern Ohio is not shown by railway elevations, since the railways in that portion of the State are largely confined to valleys. This suggests the possibility that Mr Gannett's estimate of the mean elevation, which is based largely upon railway elevations, may be too low. It is scarcely probable, however, that it falls below more than 100 feet.

eastern half of Ohio is unglaciated. Hence the reliefs of the rock surface are well exhibited in these districts.

Since the reliefs of the region under discussion depend upon the geological formations, and these formations are definitely related to the Cincinnati arch, the discussion of this arch naturally precedes that of the other reliefs. Its relation to the geological history of Ohio and Indiana is clearly set forth by Dr. Edward Orton in an early report of this Survey, as follows:[1]

All of the earlier geological history of these two States [Ohio and Indiana] as far back as it can be followed, is connected with an elevatory movement that, advancing from the southward, extended itself through most of the territory now under consideration [western Ohio and eastern Indiana]. This great uplift is most widely known in geology under the name of the Cincinnati axis, or Cincinnati anticline, a designation to which Newberry gave wide currency in his admirable account of the geological structure of Ohio.[2] The views that he sets forth as to the character of this uplift have been invalidated to some extent by the surprising discoveries of the last three years (1886–1889), but the account given by him still remains by far the best that has been published of the earlier stages of this important movement. He has shown beyond question its early origin in Tennessee and Kentucky and its gradual advance through these States. The term "axis," or "anticline," as applied to a structural feature of this character, is in some respects misleading. It is hard to qualify it so that it will not at once suggest to the ordinary reader a line or ridge, but this feature has been expressly excluded from all the statements that have been made in regard to it. Its extreme flatness and its great breadth have been insisted upon by all who have studied it. In the discussion of the physical geology of the Cincinnati group of southern Ohio it was shown that for 30 miles in an east and west direction there is scarcely any appreciable fall in the strata that compose the axis, and that all the determinable dip is a very slight and equable fall to the northward.[3] The term "axis" might well be replaced by a less confusing term, viz, the term "uplift."

* * * * * * *

The main axis of the Cincinnati uplift extends to the northwest, and not to the northeast. In the light of all that we have been accustomed to hold in regard to this great structural feature the statement here made is a surprising one, but no other interpretation of the facts is possible. The high levels of the Trenton limestone all advance to the west of north, and for this we ought to have been partially prepared by facts already in hand. The geological map of the United States has long shown a distinct westerly trend for the joint Silurian formations of the two States, Ohio and Indiana.

From Wayne and Randolph counties, Indiana, a northeasterly prolongation of high-lying Trenton rock extends through Darke, Mercer, Shelby, Auglaize, Allen, and Hardin counties to the central part of Hancock County. This prolongation may be named the Lima axis. From Hancock County an important spur of high-lying Trenton extends northerly, with a very slight westerly element in its direction. On the western side this spur is bounded by one of the most marked disturbances yet discovered in Ohio geology, viz, a monoclinal fold, or perhaps a series of connected folds of this character. The downthrow is to the west, and its total amount is not less than 200 feet. The most of the descent is accomplished within a half or a quarter of a mile, and in some cases at the rate of 1 foot in 8. This field may be appropriately styled the Findlay monocline, the Findlay break, or the Find-

[1] Eighth Ann. Rept. U. S. Geol. Survey, 1889, pp. 573–574, 576.
[2] Report Geol. Survey Ohio, Vol. I, p. 93.
[3] Report Geol. Survey Ohio, Vol. I, p. 411.

plains of northwestern Ohio. The series there and in northeastern Indiana has its members more widely separated.

Note should be taken also of feeble moraines on the border of Lake Michigan, which rise only 30 to 50 feet above the lake plains and are a mile or less in width.

THE DRAINAGE SYSTEMS.

The region under discussion is so situated as to discharge its waters to several great drainage systems. From the extreme northwest the discharge is into Lake Michigan; south of this is a small area which drains to the Illinois; from the northeast the drainage enters Lake Erie; the drainage of the greater part of Indiana is tributary to the Wabash, itself a tributary of the Ohio; the southern end of Indiana is directly tributary to the Ohio through small streams; much of Ohio drains southward through the Miami, Scioto, Muskingum, and smaller streams.

The boundaries between the several systems fall mainly within the glaciated portion and are largely determined by glacial accumulations. The only water partings within the glaciated portion which are to any marked degree coincident with an elevated rock surface are (1) in southern Randolph County between the headwaters of White River, a tributary of the Wabash, and Whitewater River, a more direct tributary of the Ohio, and (2) in west-central Ohio between tributaries of the Scioto and the Great Miami. But even here the water partings are only in a general way dependent upon the elevated rock surface, the parting itself being at a moraine.

The boundaries between some of the systems have suffered notable changes since the ice sheet withdrew from the basins of the Great Lakes and their present outlet, the St. Lawrence River. It has long been known that the Wabash once received the drainage from the portion of northern Indiana now tributary to Lake Erie and from a glacial lake occupying the western end of the Lake Erie basin.[1] The channel connecting the Maumee, a tributary of Lake Erie, with the Wabash is still a plainly marked feature along the line of the Wabash Railway from Fort Wayne to Huntington. At the eastern end of this outlet, near Fort Wayne, there are beach lines opening into it which leave no doubt as to the presence of a lake at a level corresponding to the outlet (about 775 feet above tide). The present water parting in this old outlet is determined simply by a slight accumulation of silt in the old channel near the mouths of the St.-Joseph-of-the-Maumee and the St. Mary rivers. This delta-like deposit being at the summit in the outlet, the waters were easily turned eastward down the Maumee.

Another notable change in drainage is found at South Bend, Indiana.

[1] See Report on the surface geology of the Maumee Valley, by G. K. Gilbert: Geology of Ohio, Vol. I, 1873, pp. 535-556; also Am. Jour. Sci., May, 1871.

The St. Joseph River,[1] now tributary to Lake Michigan, formerly discharged southwestward from South Bend into the Kankakee. There is still a well-defined river channel connecting the St. Joseph with the Kankakee, whose surface at the point where it leaves the St. Joseph is but 45 or 50 feet above the present low-water surface of the river. The discharge to the Kankakee was the best line open to the St. Joseph River while the ice sheet was occupying the Lake Michigan basin, but upon the withdrawal of the ice sheet and the lowering of the lake formed by it at the south end of the Lake Michigan basin, a new line was opened which had the advantage of more rapid fall. Thus the Lake Michigan system became enlarged at the expense of the Illinois River system.

The present lines of drainage within the glaciated portion of this region seldom coincide for any great distance with preglacial lines. They are in many cases too shallow to reach the bottom of the glacial deposits. Those which have cut through these deposits often encounter the uneven rock surface of preglacial ridges and hills. Throughout the greater part of the glaciated area in Indiana and in much of northwestern Ohio the present drainage channels are flowing at an elevation nearly as high as that of the preglacial ridges. The rock floors of preglacial valleys encountered in wells show that the channeling had reached a low level. In western Ohio channels stand in places within 400 feet of sea level, and in western Indiana within 250 or 300 feet. The channeling is even lower in northeastern Ohio, the rock floor of the Cuyahoga at Cleveland being but 100 feet above tide. The southern portion of Indiana has too little drift filling to prevent the main drainage lines from following preglacial valleys. Thus the Ohio along the boundary of Indiana, the West Whitewater and main Whitewater, and the lower courses of the White and Wabash rivers occupy valleys of preglacial age. These valleys are usually filled, however, to such an extent that the present streams are flowing nearly 100 feet above the old rock floors, and occasionally, as on the West Whitewater, nearly 200 feet above the old floor.

The streams within the glaciated portion of southern Ohio are seldom strictly coincident with preglacial lines for any great distance except in the case of the Ohio River, though they may have general courses nearly coincident with the preglacial lines. Thus the Great Miami below Dayton and several of its tributaries in the same section of the stream traverse lowlands with only occasional short incursions into the edge of bordering uplands. The Scioto basin probably had a preglacial drainage line along its north-to-south axis, but it was not coincident with the present Scioto River. In the unglaciated portion of Ohio great changes of drainage have resulted from the blocking of northward outlets, but the streams are only rarely thrown into courses which had not been opened by preglacial drainage lines. It is proba-

[1] This river should be distinguished from the smaller St.-Joseph of-the-Maumee.

ble that in many instances they have a flow in the reverse direction from that of the preglacial lines, especially in the central and northern portions of the State. The subject of changes of drainage in that region is now under investigation by several physiographers, and it is probable that the leading preglacial lines will ere long be traced and their connections established.

The development of the drainage lines in the glaciated portion of the region is naturally in a far from mature stage. The best-developed lines show but partially graded beds, with rapids or falls where barriers are in process of removal. Some of the streams in the northern portion have scarcely begun the opening of a channel, but flow through a succession of ponds and marshes, their principal work being the removal of barriers between the ponds. In southern Ohio, in portions of Clermont, Brown, Clinton, and Highland counties, channels are poorly developed, owing to the extreme flatness of the surface. In southwestern Indiana extensive marshes border some of the tributaries of the White and Wabash rivers. In this latter district the sluggish drainage is due to low rate of fall. In the detailed discussion which follows, the rate of fall of the main streams is considered.

In the unglaciated portion of Indiana drainage systems are strikingly in contrast with the immature systems of the glaciated portion. Except in the "sink-hole region" along the outcrop of the St. Louis limestone (see p. 483), widely branching or dendritic systems are developed, which are cut down to comparatively low and regular gradients. In some cases, however, these valleys have been so obstructed by the glacial deposits which fill the main lines of discharge that deflections of some consequence occur. At such points the valleys have the appearance of an immature state of development. The most conspicuous illustration of such a deflection is found in the Ohio Valley at Louisville. The filling with gravel brought down by the river is so great as to overspread a shelf of rock on the border of the valley. The stream in reexcavating its valley has taken a course a little to the north of the deep part of the preglacial line, and thus encountered the rock shelf. Similar slight deflections occur on the East White at Shoals and at Rockford. The falls on East White at Hindostan, a few miles below Shoals, are only in part due to the gravel filling. At that point the stream has cut across the neck of an old oxbow, the gravel filling being sufficiently high to carry the stream over a low point in the ridge that was encircled by the oxbow. This ridge is now cut down nearly to the level of the stream bed below the falls, so that scarcely 5 feet of descent is made over the rock ledges at low water, and the falls are said to be scarcely perceptible at high-water stages.

The system of underground drainage in the limestone has been so complete that surface drainage lines are very poorly developed in several counties of southern Indiana, notably Harrison, Washington, Orange, and Lawrence counties.

THE OHIO RIVER SYSTEM.

Under this system is included the Ohio, on the boundary of Ohio and Indiana, and the small streams directly tributary to it above the Wabash. The several large tributaries, the Wabash, Great and Little Miami, Scioto, Hocking, and Muskingum, are each discussed under a separate head.

The Ohio River.—A survey of the Ohio River made by the United States Army Engineers shows the length of the stream from Pittsburg to Cairo to be 967 miles, of which the southern boundary of Ohio occupies 446 miles, and that of Indiana 352 miles.[1]

The river presents an interesting series of shoals and riffles, separated by pools in which the water is deeper and the fall very low. The summary of the profile made by the Army engineers shows 187 pools with over 7 feet depth at low water, which occupy 632½ miles, an average length of 3.47 miles. Of these, 127 pools above Louisville, Kentucky, average 2.8 miles, with a total length of 363 miles; 60 pools below Louisville, with a total length of 266 miles, have an average length of 4.4 miles.

On the border of Ohio the riffles (103 in number) cover a combined length of 137 miles and have a total fall of 170 feet. The pools, with a combined length of 309 miles, have a fall of 64 feet, or but 2.5 inches per mile. The greatest fall noted for a single mile on the border of this State is at Letart Falls, Meigs County, where a descent of 3.2 feet is made. There are 11 riffles with a descent exceeding 2 feet per mile. The least fall reported is in a pool 8 to 15 miles below Cincinnati. This pool, with a length of 7 miles, has a fall of but 3.5 inches. Another pool with about as low fall is found 23 to 30 miles above Cincinnati. These are the most conspicuous pools in this section of the Ohio.

On the border of Indiana there are 55 riffles aside from the Louisville rapids. These show a total fall of 80.28 feet in a combined distance of 134.5 miles. At the Louisville rapids there is a fall of 23.09 feet in 2.25 miles. There is left but 18.13 feet for the fall of the stream in about 215 miles embraced in the pools, or only 1 inch per mile.

In general the rock floor of the valley is 30 to 50 feet below the level of the stream at low water. It rarely reaches a lower level than 75 feet below the stream. Its level is 65 or 75 feet below the stream between Evansville, Indiana, and Shawneetown, Illinois. It is thought that no place occurs in the whole length of the valley where a rock barrier crosses the entire width of the valley at a level so high as the present stream. In several places rock shelves extend out part way across the river bed, leaving a channel deep enough for the passage of boats along the opposite bank. At Letart Falls the rock is stated by

[1] Ex. Doc. No. 72, House of Representatives, Forty-first Congress, third session, January, 1871, pp. 139-153.

citizens to extend across the entire breadth of the stream, but it dips toward the east bank sufficiently to allow the passage of boats when the rock of the western part of the stream bed is above the water surface. It is thought from well data that this descent continues eastward beneath the bottom lands to a level as low as in neighboring parts of the channel. Near Ravenswood, West Virginia (see fig. 76), rocky reefs are exposed at low water fully half way across the stream bed, but wells on the bottom lands near the village show the rock floor to be at least 25 feet below the stream at low water. At Louisville it is found

FIG. 76.—Rock ledges exposed in the bed of the Ohio River opposite Ravenswood, West Virginia. The most striking features are the channels and potholes formed by the stream with its burden of sediment. Striæ are also found on these ledges, which are apparently due to the scratching by floating masses of river ice, for the locality is outside the glacial boundary. The resemblance to glacial striæ is in places very striking.

by wells and bridge soundings that a channel 25 feet or more lower than the present surface at the head of the rapids leads southwestward from near the south end of the Jeffersonville bridge a short distance and then turns westward, passing through the midst of the city.[1] Thus at the side of each of the three most conspicuous rock reefs touched by the stream a buried channel apparently occurs.

Notwithstanding the great number of riffles and shoals, the Ohio River is generally navigable throughout the entire season for small

[1] Data on this subject were furnished by Maj. William J. Davis, of the Louisville school board, and by Messrs John Ryan and John C. Oestrich, of the Louisville Pump Works.

boats drawing less than 3 feet of water. It is navigable for vessels drawing 6 feet of water during a few months of the early part of the season, but there is usually little traffic with such boats after the month of July. The canal constructed at Louisville affords opportunity for passing around the rapids during low water. During high-water stages the boats are able to pass over the rapids. In fig. 77 the average range in the stage of the lower part of the Ohio throughout the year may be seen. The diagram is constructed from tables published by the United States Weather Bureau.[1]

The valley of the Ohio River along the south boundary of Ohio and Indiana is very narrow except for a few miles near Louisville, where it has expanded itself in the Devonian shales, and in the southwestern

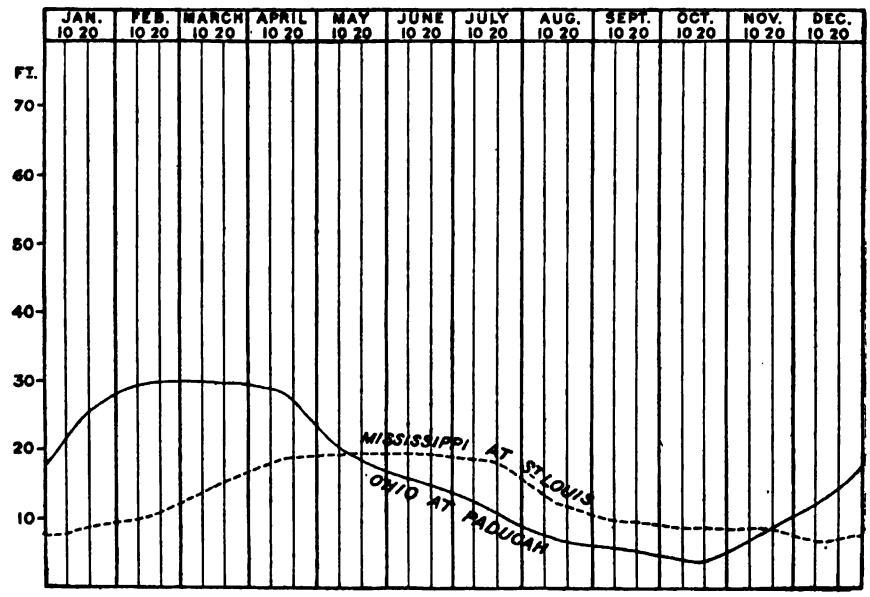

FIG. 77.—Diagram of average yearly fluctuations of Ohio and Mississippi rivers.

portion of Indiana in the Coal Measures. Its narrowness has been a subject of remark from the early days of settlement. There are very few places between Pittsburg and Louisville where its width exceeds 2 miles, and usually it is scarcely more than 1 mile wide. In the vicinity of Louisville where it crosses the low tract formed in the Devonian shales it has a width of perhaps 4 miles, but upon entering the Knobstone escarpment, below the mouth of Salt River, it narrows abruptly to a width of about 1 mile, and remains narrow for nearly 100 miles in its passage through the hard beds of Eocarboniferous age. It then enters the Coal Measures and soon attains a width of 6 or 8 miles, which it maintains for much of its course to Cairo. The only exception

[1] Report for 1891-92, pp. 495-498.

is found where it passes the elevated ridge below Shawneetown, at which place its width is reduced to about 2½ miles. The depth of the valley ranges from about 600 feet down to scarcely 100 feet, being greatest on the border of the "Pan Handle" of West Virginia and least in the lower portion of its course. Its depth seldom falls below 300 feet in the portion above Louisville, and probably averages 450 feet. The narrow portion below Louisville is about 300 feet in depth. The broad portions at Louisville and in the lower parts of its course are but 100 to 150 feet in depth. The work done by the river in excavating a narrow valley through the elevated districts is apparently commensurate with that accomplished where it has eroded a wide valley in low districts.

The entire work of the stream, however, is less than should have been accomplished by a drainage line of this size in the time since the beginning of development of drainage lines. It is far less in proportion to its size than the work accomplished by the small tributaries which enter it from southern Indiana. The explanation of this meager amount of work is found in the enlargement of the Ohio River in recent times. Investigations now in progress indicate that several independent drainage lines which formerly led northward from the Appalachian Mountains across southwestern New York, northwestern Pennsylvania, and Ohio into the Lake Erie basin, have been united to form the present Ohio. The full extent of these changes is not yet determined, nor are all of the outlets for the old river systems satisfactorily traced; but enough is known to justify the statement that the small size of the valley of the Ohio is attributable to the recent union of the several independent drainage systems.

Lesser tributaries of the Ohio.—Between the mouth of the Great Miami at the east line and the mouth of the Wabash at the west line of Indiana there are no large northern tributaries of the Ohio. This is owing to the fact that the drainage of the greater part of Indiana is westward or southward to the Wabash, instead of southward directly to the Ohio. At a point a few miles west of Madison, Indiana, a drainage line heads within 2 miles of the Ohio, and yet leads westward to the East White and thence across the State to the Wabash. Nearly all the tributaries of the Ohio in southern Indiana head within the limits of the counties that border the river, and consequently have a length of less than 30 miles. Only two, Blue River and Laughery Creek, have a length of 50 miles. In Ohio the four main northern tributaries, Great and Little Miami, Scioto, and Muskingum, absorb nearly all the drainage. A few short tributaries head between the trunks of these large systems and discharge direct to the Ohio.

In southwestern Indiana, where the altitude is low, the streams have very little fall, and are occupying broad, shallow valleys, which are not infrequently filled to depths of 50 feet or more with marshy alluvium. In the more elevated tracts, whose western border is between Rockport

and Cannelton, Indiana, the streams present valleys cut to a correspondingly greater depth. Their bottoms are narrow and well drained, the fall of the streams being adequate to give rapid escape for the surplus rainfall. The streams make a descent of 300 to 500 feet, in many cases within a distance of 10 to 20 miles. Notwithstanding this great descent there are very few waterfalls. The only notable ones occur in southeastern Indiana, where the drift deposits have obstructed the preglacial valleys and led to the development of new lines of drainage. In the unglaciated portion of southern Indiana and in southern and southeastern Ohio there are but few rock rapids, and, so far as the writer is aware, no waterfalls.

The gradients of streams, though steep, show a gradual lessening in rate of descent in passing from source to mouth and a general disregard for hardness of strata, such as results only from maturing of a drainage system. The rapid rate of descent is not favorable to the development of broad flood plains, yet there is usually a flood plain having several times the breadth of the stream bed. In this respect the tributaries, as noted above, have accomplished more work in proportion to their size than the Ohio. It is difficult to realize that the broad valleys of southwestern Indiana, 1 or 2 miles in width, were begun at no earlier date than the narrower valleys of the higher district, yet such is apparently the case in the Indiana portion and also in southwestern Ohio. In southeastern and southern Ohio changes of drainage, which have resulted in an enlargement of the Ohio and a deepening of its valley, have caused a deepening of the tributaries and the development of gorges. These gorges in the southeast part of Ohio have, at their mouths, depths of 150 to 300 feet below the old gradation plains which open out into the Ohio at these high levels.

With the exception of a few streams in southwestern Indiana, these small tributaries of the Ohio have water power of considerable value. Gristmills, as well as sawmills, utilized this power extensively in the early days of settlement, before steam mills were introduced. Blue River, in southern Indiana, still supplies several gristmills, but on the majority of the streams the water power is abandoned. In general these small tributaries maintain a good flow throughout the dry season, since the limestone and sandstone strata which they have channeled often furnish copious springs. In some cases a single spring furnishes enough water to run a mill. Harrison spring, a tributary of Blue River, near White Cloud, Indiana, furnishes enough water power to run both a gristmill and a sawmill.

In the report on water power of Ohio streams, in the Tenth Census, Prof. Dwight Porter furnishes a table showing that the minor tributaries of the Ohio in that State were at that time supplying 150 mills and other manufacturing establishments with a total of 3,266 horsepower.[1]

[1] Tenth Census of the United States, 1880, Vol. XVII, pp. 487, 488.

There are conditions unfavorable to the use of water power on portions of several streams in southern Indiana. The limestone belt of Harrison and Crawford counties has an extensive subterranean drainage, and it is not rare for a surface stream to lose a portion of its water through leakage into the subterranean channel. In this way Indian Creek, just below Corydon, becomes throughout much of the year entirely dry. There is also a disadvantage resulting from the backwater of the Ohio. This, however, affects the streams only for a short distance near the mouth, and for a few days, or at most a few weeks, of the year.

THE WABASH RIVER SYSTEM.

The drainage basin of the Wabash embraces an area of about 33,000 square miles, distributed as follows: In Ohio, 400 square miles; in Indiana, 24,350 square miles; in Illinois, 8,250 square miles. It drains, therefore, slightly more than two-thirds of Indiana, the area of the State being 35,910 square miles. Of the portion in Indiana, about one-half is embraced in the drainage areas of the East and West White rivers. By including these drainage areas with the Wabash the entire watershed has a nearly symmetrical, broadly ovate form. Not including the White River system, the Wabash watershed is an unsymmetrical, elongated tract, curving around White River.

But a small part of the Wabash watershed lies outside the glacial boundary. The Wabash and West White rivers lie within that boundary for their entire length. The East White flows in a glaciated region to western Jackson County, but from that point to western Martin County is in an unglaciated tract. It enters a drift-covered district in its lower course near the corners of Martin, Davis, and Dubois counties, but apparently occupies its preglacial valley there, as in the unglaciated tract. The greater part of this system being within the limits of glaciation, and in a region where the drift coating is sufficiently thick to conceal more or less completely the preglacial valleys, it has been largely developed in interglacial and postglacial time.

Wabash River.—The valley occupied by the Wabash River has not had a uniform development from source to mouth. In its upper part, from the source to Huntington, Indiana, the valley has been entirely formed by the present stream and is a shallow and narrow trench. At Huntington the river enters the old westward outlet of a glacial lake that occupied part of the basin of Lake Erie, and which has a valley several times as large as that occupied by the Wabash above this point. This old lake outlet opened a new or postglacial line of drainage in its westward course across Indiana, except for a few miles in the vicinity of Lafayette, where it crosses or follows a preglacial valley for a few miles. It has been compelled to do considerable excavation in rock from Huntington down as far as Covington, and still carries rapids at

several points. Below Covington the stream follows very nearly the line of a partially filled preglacial valley, and its work has been largely the removal of a portion of the glacial deposits left in that valley. It makes, however, some deflections into the edge of the uplands, cutting off points of the bluffs. At such places the channel is occasionally in process of excavating rock. The cause for these deflections is not in all cases clear, but it is probable that in the majority of cases the filling was such that the stream was free to pass across these points, and thus take a more direct course than that of the old line around them. In some cases it is possible that the ice sheet may have had its eastern edge along the line of the Wabash sufficiently long to cause a stream flowing on its border to cut across projecting points.

The length of the valley occupied by the Wabash is about 450 miles; but the length of the stream is fully 500 miles, for the river in its lower course makes several oxbow curves within the valley. The source of the river is about 1,000 feet above tide, while its mouth at low water is but 311 feet. The average fall, if we estimate the stream to have a length of 500 miles, is therefore about 16½ inches per mile. The rate of descent is far from uniform, being much more rapid in the upper portion than in the lower. There are also many rapids, separated by pools or sluggish portions of the stream. The elevation of the stream is accurately determined at many points, but in the absence of a careful measurement of the length of the stream the rate of fall is only approximately known. The section above the point where the river enters the old lake outlet, estimated to have a length of 100 miles, has a fall of about 300 feet, or 3 feet per mile. Railway levels and canal surveys at the point where the river joins the old lake outlet show its elevation to be very nearly 700 feet above tide, the altitudes reported varying between 696 and 699 feet. The canal survey below Huntington shows a fall of 32 feet to the mouth of the Salamonie, a distance of about 15 miles, and a fall of 34 feet between the mouth of the Salamonie and the mouth of the Mississinewa, a distance of perhaps 20 miles. In the next 20 miles, to Logansport, there is a fall of 50 feet. From Logansport to Lafayette, a distance of about 50 miles, there is a fall of 77 feet. From Lafayette to Attica, a distance of 25 miles, the fall is but 19 feet, and from Attica to Covington, a distance of 20 miles, but 17 feet. From Covington to Terre Haute, a distance of about 55 miles, there is a fall of only 22 feet, this being the lowest gradient for so long a section found on the river. From Terre Haute to the mouth of White River an accurate survey by the United States Army engineers shows a fall of 71.18 feet in a distance of 122.55 miles, or about 7 inches per mile. In this distance there are 13 riffles, each but a fraction of a mile in length, which have a combined fall of 17.86 feet. These reduce the fall of the 120 miles not embraced in the riffles to 53.32 feet, or 5.33 inches per mile. The greatest fall at a riffle in this section of the

Wabash is at Grand Rapids, just above the mouth of White River, where it amounts to 4.5 feet.[1] The fall from the mouth of the White is 65 feet in a distance of perhaps 90 miles by the windings of the stream. The following table includes the data upon which the above statements are made:

Table of altitudes and distances along Wabash River.

Location.	Estimated distance.	Altitude.	Fall per mile.
	Miles.	*Feet.*	*Inches.*
Source	0.0	1,000.0	00.00
Huntington	100.0	699.0	36.00
Mouth of Salamonie River	15.0	667.0	25.56
Mouth of Mississinewa River	20.0	633.0	20.40
Logansport	20.0	583.0	30.00
Lafayette	50.0	506.0	18.48
Attica	25.0	487.0	9.12
Covington	20.0	470.0	10.20
Terre Haute	55.0	447.7	4.80
State line	14.6	440.6	5.80
Hutsonville, Illinois	29.0	424.6	6.60
Vincennes	46.4	398.8	6.60
Mouth of White River	32.5	376.5	8.30
Grayville, Illinois	28.0	365.0	5.00
Mouth of Little Wabash	46.0	323.0	11.00
Mouth of river	16.0	311.0	9.00

In the early days of settlement the Wabash River was made use of for the shipment of produce down the stream in barges; but upon the construction of the Wabash and Erie Canal, which leads from Terre Haute up the valley to Huntington and thence up the old lake outlet to Fort Wayne and down the Maumee to Toledo, the shipments of the upper portion of the valley changed to the eastern seaboard, and the shipments down the river were largely discontinued. The river has, therefore, been but little used for navigation. It would require a great amount of improvement to render it navigable at ordinary stages, and the demands of commerce seem at present scarcely to justify any outlay. Railways cross or follow the valley in such a manner as to offer the best of facilities for shipment of produce.

The canal, long used as a means of water transportation, has been supplanted by the railroad, but is still partially utilized as a hydraulic force. The cities along the Wabash from Huntington to Terre Haute may thus, at comparatively slight expense, avail themselves of an excellent water power.

[1] Geology of Indiana, Thirteenth Report, 1883, pp. 69-70.

Salamonie River.—The Salamonie River, a southeastern tributary entering the Wabash a few miles above the city of Wabash, has a length of about 75 miles. Its source is on the northern slope of the elevated limestone district of eastern Indiana, at an altitude of about 1,000 feet above tide. Throughout the greater part of its course the river follows a plain on the south border of the Salamonie moraine. Its descent is measured by the descent of the plain, except in the lower 40 miles, where it has deepened its channel to enter the old lake outlet. Sufficient time has not elapsed since the river began flowing for it to form a regular gradient. It can scarcely be said to have developed any valley except in the lower 40 miles, the bed of the stream in its upper course being seldom more than 20 or 25 feet below the bordering plain. The descent from Portland to Montpelier is less than 3 feet per mile, but in the 40 miles from Montpelier to the mouth the average descent is about 4 feet per mile.

The Mississinewa River.—The Mississinewa River, a southeastern tributary entering the Wabash near Peru, has a length of about 100 miles. Its source is in western Ohio, 10 or 12 miles beyond the State line, on the north slope of the elevated limestone district which occupies eastern Indiana and western Ohio. At its source the altitude is probably 1,100 feet above tide. In the 25 miles from its source to Ridgeville, Indiana, the stream has a fall of about 5.5 feet per mile, descending with the plain, which it follows on the south border of the Mississinewa moraine, and cutting but 15 to 30 feet into the plain. From Ridgeville to Marion, a distance of 50 miles, the rate of fall is but little more than 3 feet per mile. The stream in this distance has deepened its channel slightly, but at Marion is scarcely 50 feet below the bordering plain. The most of the work accomplished by the stream is in the section between Marion and the mouth, a distance of only 30 miles. Its fall in this section is about 5.5 feet per mile, or fully as great as in the headwaters. The depth of the channel increases from about 50 feet at Marion to fully 100 feet in the vicinity of its mouth. It is excavated mainly in drift, but at some points has extended a few feet into the underlying rock strata.

The lower portion of this stream furnishes water power, which has been put to use at several points.

Eel River.—Eel River, a northeastern tributary of the Wabash, entering at Logansport, has a length of about 85 miles. Its source is on the inner border of the great interlobate moraine a few miles north of Fort Wayne, at an elevation of about 850 feet above tide. The average fall of the stream is very nearly 3 feet per mile, the elevation of the mouth being 583 feet. The following table of distances and elevations is based upon Williams's list of altitudes given in the Tenth Report of the Indiana Geological Survey.

Altitudes along Eel River.

	Distance from mouth.	Altitude.
	Miles.	*Feet.*
Source, about	85	850
Columbia City	70	816
Collamer	58	768
Liberty Mills	50	750
North Manchester	45	721
Eel River railroad bridge in Miami County	30	688
Mouth, at Logansport	0	583

In this stream, as in the Mississinewa and Salamonie, the headwater portion has a poorly developed channel and sluggish current. It is only in the lower 25 or 30 miles that erosion of any consequence has occurred. Even here the valley scarcely exceeds 50 feet in depth.

Tippecanoe River.—Tippecanoe River is the main northern tributary of the Wabash within the State of Indiana. It has a length of about 125 miles, and drains a belt averaging perhaps 20 miles in width. Its source is in the midst of the great interlobate moraine of northeastern Indiana, at an elevation of nearly 1,000 feet above tide. It descends the northwest face of the moraine from southwestern Noble County into Kosciusko County, reaching a level 800 feet above tide north of Warsaw. It follows the north border of the moraine a few miles southwestward to the point where the Saginaw and Erie moraines become differentiated. It then passes through a gap in the Saginaw moraine and enters a sandy plain formerly occupied by the waters of the glacial lake Kankakee. After traversing this plain a distance of about 60 miles it leaves the old lake area near Monticello and passes through an Erie moraine which follows the northwest border of the Wabash River and enters the Wabash from a narrow plain on the inner slope of this moraine.

Although bordered in places by elevated knolls and ridges in the upper portion of its course, it has no well-defined valley, nor has it excavated a valley of much depth in the old lake bottom. The main excavation occurs in the lower 30 miles of its course, and even here its channel is narrow and scarcely reaches 100 feet in depth. In this lower portion the rate of fall is about 3 feet per mile. The fall is less in the section traversing the old lake bottom, being about 150 feet between Rochester and Monticello, a distance of 60 miles. The great fall of the upper portion is chiefly made in short sections connecting marshes whose levels become successively lower in passing down the slope of the moraine.

The lower portion of the stream furnishes water power which has been utilized at several points by flouring mills. The source of the

stream being in a region fed by marshes, the run-off is more regular than in the case of rivers with better-drained areas which have a rapid run-off. It seldom, therefore, reaches a sufficiently low stage to lessen the value of the water power.

Small tributaries of the Wabash between Tippecanoe and White rivers.—Below the mouth of the Tippecanoe there are several creeks having a length of 35 to 75 miles. One of the longest is Wildcat Creek, which enters from the east just above the city of Lafayette. This stream has a length of about 75 miles and a fall of fully 400 feet. Its course being through a till area where the run-off is rapid and but a small portion of the rainfall reaches the stream by percolation, it is very irregular in its volume, being flooded at times of freshet and nearly dry in seasons of drought.

Sugar Creek, another eastern tributary which enters in northern Parke County, is also fully 75 miles in length and has a fall of not less than 400 feet. The lower course of this stream is in places excavated in rock strata to a depth of 50 to 75 feet or more, and furnishes much picturesque scenery. Like Wildcat Creek, it is subject to great variations in volume because of the rapidity of its run-off.

Other tributaries worthy of mention are Coal Creek, which enters in southern Fountain County, whose length is about 35 miles; Big Pine Creek, a northern tributary entering near Williamsport, which has a length of about 40 miles; Big Raccoon Creek, which enters near Montezuma, in western Parke County, and whose length is not less than 60 miles; and Busseron Creek, which enters the Wabash about 10 miles above Vincennes and has a length of about 35 miles. Two western tributaries of the Wabash, Big Vermilion and Little Vermilion rivers, enter it within the limits of Indiana, but their drainage basins lie almost entirely in Illinois.

Big Raccoon still furnishes water power for several mills, but steam is used part of the year in every instance. Many mills on the streams just mentioned have been abandoned. By a judicious system of ponding they probably would furnish a sufficient amount of water for ordinary milling purposes.

West White River.—The chief tributary of the Wabash is West White River, which enters it from the east at a point about 90 miles from the mouth. If we include with the West White its entire system of drainage it will embrace about one-third of the State of Indiana, or an area about as great as that drained by the Wabash and its other tributaries within that State. The West White proper, however, drains only about one-sixth of the State, the drainage basin of the East White, its principal tributary, being nearly as great as that of the main river.

The source of the West White River is in Randolph County, near the east line of the State. The course of the stream is westward to Hamilton County, a distance of nearly 75 miles, where it turns abruptly

southward and leads in a course somewhat west of south to the Wabash River.

The length of the valley of this stream is about 275 miles, but this does not represent the length of the stream, for in its lower part it winds greatly within its valley, adding perhaps another hundred miles to its length. The estimates given below are, however, based upon the length of the valley rather than that of the stream. They indicate the condition when the stream is out of bank, as is occasionally the case in high-water stages.

At its source the stream has an elevation of not less than 1,175 feet, while at its mouth the elevation is but 375 feet above tide. It has therefore an average fall of nearly 3 feet per mile, or more than double the average fall of the Wabash River, and about five times the rate of fall of the portion of the Ohio along the south boundary of the State. In its upper 15 miles the fall is estimated to be about 8 feet per mile, in the next 25 miles about 6 feet, and in the succeeding 20 miles about 5 feet, making a fall of 375 feet in a distance of 60 miles, which is reached near the city of Anderson. Below Anderson the fall for the 50 miles to Indianapolis is nearly 2½ feet per mile. Below Indianapolis, for about 30 miles, the fall exceeds 3 feet per mile. In the remaining 130 miles of its course there is a fall of but 185 feet, or slightly less than 1½ feet per mile.

With such a rapid fall and with the large volume of water which is carried by this stream excellent advantages are afforded for the use of water power. But so far as the writer could ascertain there are no mills in use below Indianapolis, and those on the headwaters are generally idle. The headwater portion of this stream leads through the midst of the natural-gas belt of Indiana, where fuel for manufacturing or milling purposes can be obtained at such slight expense that water power is no cheaper; indeed, it is more expensive sometimes to keep the dams in order than to obtain the gas for fuel. Should the supply of gas greatly decrease and the cost of obtaining it become greater than that of keeping the dams in repair there will naturally be a return to the use of the water power.

This stream, like the Wabash, can not be navigated except in flood stages, unless expensive improvements are made. It has in part a rocky bottom, a feature which would make improvement of the channel expensive, as would also the rapid fall.

Aside from its main tributary, East White River, there are but two tributaries of White River which exceed 50 miles in length, namely, Fall Creek, an eastern tributary entering just above Indianapolis, and Eel River, a western tributary entering at Worthington, in northern Greene County.[1] There are several tributaries with a length of over 20 miles, as follows: Pipe Creek, which drains northern Madison

[1] This river should be distinguished from a stream of the same name entering the Wabash at Logansport.

County, length about 25 miles; Duck Creek, draining the district immediately west of Pipe Creek, length 20 to 25 miles; Cicero Creek, draining southern Tipton and northern Hamilton counties, length about 30 miles; Eagle Creek, draining southeastern Boone and northwestern Marion counties, length about 40 miles; Lick Creek, draining eastern Hendricks and northern Morgan counties, length about 30 miles; Indian Creek, draining southwestern Johnson and southern Morgan counties, length 20 to 25 miles; Beanblossom Creek, draining northern Brown and northern Monroe counties, length about 45 miles; Richland Creek, draining northeastern Greene County, length about 25 miles.

Fall Creek has an elevation at its source of at least 1,000 feet and at its mouth of about 700 feet. Fully half of the 300 feet of descent is made in the upper 20 miles, leaving a fall of 150 feet for the lower 40 miles.

Eel River has a length of nearly 100 miles. Its east fork, known as Mill Creek, is about 40 miles in length, and its west fork, known as Walnut Creek, fully 50 miles. Below the junction of these forks the stream has a length of about 45 miles, if the minor windings of the channel are disregarded. This stream in the early days of settlement furnished water power for several mills, but with the building of railways and establishment of steam mills at the villages the water power has gradually gone into disuse.

East White River.—This large tributary enters the West or main White River about 40 miles above its mouth. It drains the district immediately east of that drained by the main river and has an area nearly as great, there being about one-sixth of the State tributary to it.

The headwater portion above Columbus, Indiana, is usually known by the name of Blue River, the name East White being applied to the stream below its junction with Flatrock Creek at that city. The name Driftwood is also applied to the lower portion of the river. Inasmuch as there is another stream within the State called Blue River, it is unfortunate that this name is applied to the headwater portion of East White.

The upper half of the drainage basin of the East White River lies within the glaciated districts of eastern and southeastern Indiana. The streams find their sources in the elevated Niagara limestone belt, in the eastern part of the State, and descend rapidly westward to the Devonian shale area. The main stream leads through the western part of the drainage basin, and hence receives nearly all its tributaries from the east. The drainage system is, therefore, very unsymmetrical.

Although these headwater tributaries make a great descent in passing from the Niagara down to the basin of Devonian shale, they have carved very insignificant channels. The valleys are usually so shallow that their bridges may be seen for miles back from the borders of the streams. A portion of the Muscatatuck drainage system is, however, characterized by deeper channels, a feature which is probably attribu-

table to the greater age of that system. It lies outside the limits of the newer drift, while the principal tributaries of the East White farther north flow, throughout most of their course, within the limits of the newer drift sheet.[1]

The northern tributaries, Blue River and Flatrock Creek, have their sources in northeastern Henry County at an elevation of about 1,100 feet above tide. They make a descent of about 500 feet in the 100 miles from their source to the junction at Columbus, an average fall of about 5 feet per mile. In the lower 35 miles of its course, from Shelbyville to Columbus, Blue River has a fall of about 4½ feet per mile, nearly as great as the fall of the headwater portion above Shelbyville. From Columbus to the mouth of the Muscatatuck, a distance of 55 miles, the average fall is very nearly 20 inches per mile. In the remaining 125 miles, where the stream is flowing in a preglacial valley, the fall is about 10 inches per mile. In this portion there are, however, occasional riffles and rapids in which a descent of several feet is made within a mile. The most conspicuous of these rapids is at Hindostan, where a fall of about 5 feet occurs. At this point the stream, as already noted, has cut off an old oxbow and is excavating the rock in the ridge encircled by the oxbow.

The Muscatatuck River, in its lower 25 miles, has very little fall compared with that of the neighboring section on East White River. At the railway crossing south of Seymour the bed of the Muscatatuck is 40 feet lower than at the crossing on the East White immediately north of Seymour. This difference in gradient is due to a filling of the East White Valley by deposits of gravel at the later ice invasion. As the Muscatatuck drainage system lies outside the limits of this later ice invasion or the reach of its waters, its valley remains unfilled. The fall on the lower 25 miles of the Muscatatuck is apparently not more than 10 feet, while on East White River, in the 25 miles above the mouth of the Muscatatuck, there is a fall of about 50 feet.

The portion of the East White River Valley lying within the unglaciated districts of southern Indiana is cut to a comparatively low gradient, notwithstanding the hard rock formations through which its course is carved. The valley at present is silted up to a height of perhaps 100 feet above the preglacial rock floor. The bluffs rise 200 to 300 feet or more above the present valley bottom, thus giving the preglacial valley a depth of 300 to 400 feet. Notwithstanding this great depth and the hardness of the formation, the width of the valley is seldom reduced to less than one-third mile, and probably averages more than one-half mile between rock bluffs. The valley of this stream, like that of the Ohio in the corresponding section, presents a series of oxbow curves, with very little straight channeling.

Within this unglaciated portion the East White receives one impor-

[1] See Third Ann. Rept. U. S. Geol. Survey, pp. 333-334, for discussion of the extent of the newer drift; also the present paper, pp. 434-438.

tant northern tributary, Salt Creek. This stream has a length of about 60 miles from its headwaters, in Brown County, to its mouth, near Bedford, in Lawrence County. It drains the greater part of the elevated district in Brown, Jackson, Monroe, and Lawrence counties. In its headwater portions, in Brown County, it has valleys cut to a depth of 300 and occasionally 500 feet below the level of the neighboring hills, and has developed a dendritic system of drainage strikingly in contrast with the irregular and unsymmetrical drainage systems of the streams within the drift-covered regions to the north and east. At its headwaters the valleys have been filled to a marked degree by deposits of sand and gravel made by streams issuing from the edge of the ice which for a time overhung the northern portion of Brown County. The valley is apparently filled to nearly as great an extent as the portion of the East White with which it connects. Its rate of fall is more rapid than that of the East White, but is less rapid than that of some of the large streams of the glaciated district. The fall of the north fork from Nashville, a few miles from its source, to the mouth of the stream is only about 150 feet, or scarcely more than 3 feet per mile.

Lost River, a tributary entering East White River from the east, in southern Martin County, has a length of about 50 miles. The peculiar subterranean drainage of a portion of this stream is discussed below (p. 483). It has a very narrow drainage basin compared with that of Salt Creek.

It is reported that the East White River was navigated in the early days of settlement by small boats and barges as far up as Hindostan, a distance of about 40 miles from its mouth, the valuable quarries at Hindostan being the incentive for carrying navigation to this point. Navigation is, however, difficult except at times of high water, and the railway facilities now offered make it unnecessary to attempt it.

East White River and many of its tributaries furnish a large amount of available water power, of which at present very little use is made. At several points mills have been abandoned and the dams removed. It should be noted, however, that on some of the small tributaries mills are still in successful operation. Thus on Boggs Creek, a small northern tributary entering just below Shoals, a small gristmill is run entirely by water power. As this creek has a drainage basin above the mill site with an area of less than 75 square miles, the amount of water available for water power is rather unusual. The supply is, however, largely from springs along its course. On Lost River there is a mill known as the Wagner Mill, located at Windom, which is run entirely by water power.

Many mills were constructed on the headwater portions of the East White drainage system, but only a few are now in operation. Some of these mills are said to have furnished products that have gained a continental reputation, having found a market in Europe as well as this country.[1]

[1] Eleventh Ann. Rept. Indiana Geol. Survey, 1881, p. 210.

Patoka River.—The Patoka River drains a narrow belt along the south border of the drainage basin of the East White River. The stream has a length of over 100 miles, but its drainage basin nowhere exceeds 20 miles in width. Its source is in the hills of the Chester sandstone and millstone grit in southern Orange County, at an altitude of about 800 feet. Its mouth is just below that of White River, at an elevation of 375 feet above tide. This valley has not been personally visited, but is reported to have a remarkable breadth for so small a stream.[1] It is also reported to have a very sluggish stream in its lower course, through Gibson County.

WHITEWATER RIVER SYSTEM.

Several streams which have their sources in a moraine in southern Randolph County, Indiana, and southwestern Darke County, Ohio, converge southward to form the Whitewater River. These are known as West Fork, Martindale Fork, Greens Fork, Nolands Fork, and East Fork. The first four become united between Cambridge City and Connersville to form the West Whitewater; the fifth (East Fork) unites with the West Whitewater at Brookville. The area of the Whitewater drainage basin is about 1,500 square miles. The headwater portions for 15 to 20 miles are flowing in channels cut in the drift. The East Fork then, near Richmond, enters the rock, and has carved its course partly in rock from that point to Brookville. The West Fork encounters rock only at a few points. Below Connersville it is in a partially filled preglacial valley with broad bottom and elevated uplands on either side.

The West Fork, with its several headwaters, constituted an important line of drainage for the waters from the ice sheet at the time the moraine above referred to was forming, and probably also at earlier stages in the Glacial period. It is in consequence a gravel-filled valley, and the work of the present stream has been merely the removal of a small portion of these gravel deposits. Above Cambridge it has cut scarcely 20 feet into these deposits. The depth gradually increases southward to Brookville. At Brookville and below that city it has formed a channel 60 to 75 feet in depth. The surface of the gravel deposits had a southward descent amounting to not less than 6 feet per mile throughout the entire length of the stream; in the headwater portion above Cambridge it was nearly 10 feet per mile. From Cambridge to the State line at Harrison, Ohio, a distance of scarcely 70 miles, the gravel deposits have a descent of 350 feet, or fully 5 feet per mile. The present stream, having cut about 50 feet deeper into the gravel deposits at Harrison than at Cambridge, has a fall of nearly 6 feet per mile.

The Whitewater Valley Canal, leading from the Ohio River at Lawrenceburg to Hagerstown, only 20 miles from the head of the West Fork, was for many years an important line of transportation and also a valuable hydraulic force. The canal is no longer used for navigation,

[1] Fourth Ann. Rept. Indiana Geol. Survey, 1872, p. 239; Fifth Ann. Rept., 1873, p. 397.

having been supplanted by the Whitewater Valley Railway. The water power is at present used only along a small portion of the canal. The great advantage for water power here offered should be more generally used by the cities located in this valley.

GREAT MIAMI RIVER SYSTEM.

The Great Miami is the main system of southwestern Ohio. Exclusive of the Whitewater, it has a drainage area of nearly 4,000 square miles, or about one-tenth of the State of Ohio. Its headwaters are at the continental watershed, and it drains the greater part of the Cincinnati arch from that watershed south to the Ohio River. One of the eastern tributaries, Mad River, heads in the elevated tract near Bellefontaine, at an elevation of fully 1,200 feet above tide. The other headwaters, except the Whitewater, have their sources at an elevation of about 1,000 feet. The Whitewater, as noted above, rises in the higher part of eastern Indiana, at an elevation of nearly 1,200 feet.

The valleys of the headwaters as far down as the vicinity of Dayton are narrow and comparatively shallow postglacial channels, with courses independent of preglacial drainage lines. Mad River, it is true, occupies a broad trough-like valley, but on its borders are moraines which cause most of the relief, the bluffs being generally but 20 or 30 feet high. Below Dayton the Miami and some of its tributaries occupy preglacial lines which are only partially filled with glacial deposits. The work of the present streams has been in the main a reexcavation of the valleys. In this work they have fallen far short of reaching the old rock floors, which lie 100 to 200 feet below their beds. The depth of this reexcavation is but 50 to 100 feet, and the width is but a small fraction of that of the old valley, seldom so much as one-fourth as great. The contrast between the southern and the northern portion of this drainage basin therefore is not found in the work of the present streams, but is due to the less complete concealment of preglacial drainage lines.

The fall of the Miami is rapid throughout its entire length, being seldom less than 3 feet and usually over 4 feet per mile. The streams in this drainage system seldom reach a very low stage in seasons of drought, for the valleys are usually filled with gravelly or sandy deposits which furnish strong springs. Even in the small tributaries, water-bearing beds outcrop along the banks or bluffs.

This stream and several of its tributaries afford valuable water power, the utilization of which is discussed by Prof. Dwight Porter in the Tenth Census Report.[1] From this report it appears that a total of 9,431 horsepower was used in 1880 by 290 mills, manufactories, etc., on the Miami and its tributaries, including Whitewater River.

[1] Tenth Census of United States, 1880, Vol. XVII, pp. 478–487.

LITTLE MIAMI RIVER SYSTEM.

The Little Miami drainage basin lies immediately southeast of the Great Miami. It is much less extensive, the area being less than 2,000 and probably not more than 1,850 square miles. The source of the main stream is a few miles southeast of Springfield, and the mouth is just east of Cincinnati, the length of the stream being scarcely 100 miles. The East Fork has its source a few miles north of Hillsboro, and joins the main stream just above its mouth.

This stream and its tributaries have courses through areas of thin drift, and, in consequence, are generally bordered by rocky bluffs. The headwater portions have shallow valleys, but the lower portion of the main stream, from a few miles below Xenia to the mouth, occupies a valley 200 to 300 feet or more in depth. This deep portion apparently unites two or more independent preglacial valleys. The tributaries are generally in shallow valleys to within a few miles of the main stream The stream as a rule falls at the rate of 3 to 6 feet per mile. The headwaters of the main stream are fed by numerous springs issuing both from the rock and from gravelly drift beds. The lower course and the East Fork, with its tributaries, are not so well favored by springs, for they traverse the shale beds of the Hudson River group, and the coating of drift is mainly till.

The main stream with its headwater tributaries furnishes considerable water power, but the remainder of the drainage system is rather unreliable. A table of statistics concerning the utilization of water power on the Little Miami and tributaries appears in Professor Porter's report above cited. At the time the report was made (1880) 59 mills and manufacturing establishments were using 1,947 horsepower.

THE SCIOTO RIVER SYSTEM.

This river system drains a strip of land 10 to 50 miles in width and about 170 miles in length, mainly in the west-central portion of Ohio, and discharges into the Ohio River at Portsmouth. The main stream has a length, including its curves, of about 210 miles, and with its several tributaries drains an area of 6,400 square miles. The following table of drainage areas of the Scioto and tributaries is taken from Professor Porter's report.[1]

Drainage area of the Scioto and tributaries.

	Sq. miles.
Olentangy River	547
Big Walnut Creek	513
Darby Creek	592
Deer Creek	423
North Paint Creek	236
Main Paint Creek	857
Scioto River above Columbus	1,139
Scioto River	6,400

[1] Tenth Census of the United States, 1880, Vol. XVII, p. 477.

The source of the main stream is in eastern Auglaize County, at an altitude of about 1,050 feet. For nearly 60 miles its course is eastward into the Scioto basin, and in that distance it falls to about 900 feet, or only 2½ feet per mile. It then turns south and traverses the central portion of the Scioto basin. In the 40 miles from the bend of the river to Columbus the fall is about 5 feet per mile, a descent of 200 feet being made. From Columbus to the mouth, a distance of 110 miles, there is an average fall of about 2 feet.

The source of one of the headwater western tributaries, Rush Creek, is much higher than that of the main stream, being nearly 1,300 feet above tide. Some of the eastern tributaries have sources nearly 1,200 feet above tide.

The valleys of the Scioto and tributaries as far down as Circleville are postglacial, and are shallow and narrow, the depth seldom reaching 50 feet and the width seldom exceeding one-fourth of a mile. Paint Creek from Bainbridge eastward nearly to Chillicothe occupies a preglacial valley about a mile in width and 300 feet in depth. Before joining the Scioto, however, it turns into a narrow channel in the south bluff.[1] A short distance below Chillicothe the hills close in on the Scioto on both sides, and the remainder of its course is through a deep valley bordered by hills 400 feet or more in height. This deep valley was but partially filled by the gravelly drift carried southward from the ice sheet. In this drift the present stream has cut an insignificant valley one-fourth to one-half mile wide and 50 to 75 feet in depth. The preglacial drainage was northward from eastern Kentucky and from the Kanawha system of West Virginia into the Scioto basin along an abandoned channel a few miles east of the Scioto, from Wheelersburg to Waverly, Ohio, as indicated on the glacial map (Pl. XXXVI). The preglacial drainage along the Scioto Valley from Portsmouth northward was apparently the reverse of the present, but this matter needs further investigation.

There is a less regular flow in the streams of this basin than in those of the Great Miami. This difference is due to the more compact soil of the Scioto basin and to consequent freer escape of the rainfall. From Circleville to the mouth of the Scioto, however, the course of the stream is through a belt of gravel which tends to equalize the flow. The headwater portion of the main stream has poor drainage, owing to the slight fall, and marshes tend to give that portion a regular flow.

Professor Porter's report on water power of the Scioto and tributaries indicates that the main stream has been utilized less than some of the tributaries. The mills reported on the main stream are confined to the rapidly descending portion in Delaware and Franklin counties above Columbus. There were at that time (1880) 8 flouring mills, which utilized 202 horsepower. On the tributaries 103 mills of various kinds (flouring, saw, woolen, paper, etc.) utilized 2,731 horsepower.

[1] See Professor Orton's description of Paint Creek Valley: Geology of Ohio, Vol. II, pp. 653–655.

HOCKING RIVER SYSTEM.

This small river system has its headwaters in the east border of the Scioto basin, near Lancaster, and connects with the Ohio at Hockingport, a few miles below Parkersburg, West Virginia. It embraces an area of only 1,200 square miles, and the length of the main stream is scarcely 100 miles. It is possible that the present valley has been formed by the union of several small independent preglacial streams, but insufficient study has been given it to warrant full interpretation.

The valley of the main stream is gravel-filled throughout much of its length, as are also valleys of tributaries which head within the glacial boundary. Tributaries outside the glacial boundary, such as Sunday Creek, have silt filling. Owing to gravelly deposits and to springs from sandstone strata which form the bordering bluffs, this stream maintains a fair flow through seasons of drought.

The fall of the stream is about 250 feet between Lancaster and the mouth, a distance of about 90 miles. Of this fall nearly 100 feet is made in about 25 miles below Lancaster. Professor Porter reports 18 mills on this stream and its tributaries, utilizing 451 horsepower.

MUSKINGUM RIVER SYSTEM.

The Muskingum River drains the greater part of eastern Ohio and has an area estimated by Professor Porter at 7,740 square miles. The name Muskingum is applied only to the lower portion, below the junction of the Tuscarawas and Walhonding rivers, a length of 109 miles. From the sources of the Walhonding and Tuscarawas to their junction is a distance of 100 miles, thus giving the basin a length of 200 miles, or about as great as that of the Scioto. It is a broadly branching drainage system at the north with an extreme width of about 100 miles. At the south it receives few tributaries, there being none of importance below Zanesville.

The following estimates of the areas of the drainage basins are taken from Professor Porter's report:

Drainage areas of Muskingum River and its tributaries.

	Sq. miles.
Walhonding River	2,159
Tuscarawas River	2,547
Wills Creek	815
Licking River	703
Muskingum and tributaries below Zanesville	1,175
Total area of Muskingum system	7,740

The present system of drainage departs greatly from the preglacial system. Not only have changes occurred in the glaciated district, which encroaches on the north and west borders of this drainage system, but also in the course of discharge for the main river. Prof. W. G. Tight has shown that this drainage system is connected with the Scioto system by a broad valley leading from Dresden (a few miles above Zanesville) westward past Newark to the Licking reservoir and thence into

the Scioto basin north of Circleville.[1] It is thought by Professor Tight that the Muskingum discharged through this valley to the Scioto basin. The available data, however, do not, in the present writer's opinion, make it clear whether the direction of flow was from the Muskingum to the Scioto or from the Scioto to the Muskingum. The deep and broad channeling of the Cuyahoga at Cleveland recently brought to notice by Mr. Warren Upham[2] and the great thickness of drift in the lowlands on the present watershed between the Tuscarawas and Cuyahoga, showing a rock floor there as low as the surface of Lake Erie, opens the question of a possible northward discharge for the Muskingum, which would carry with it the Scioto. The present southward course from Zanesville is evidently but recently opened, the valley being very narrow compared with the abandoned valley or with the valleys of several main tributaries, and there being a higher rock floor than in portions of the drainage system farther north. The present writer, as well as Professor Tight, places the old divide between the Muskingum system and a small stream leading to the Ohio, at a point near the line of Muskingum and Morgan counties.

Numerous changes of drainage have occurred in the glaciated portion of the drainage system, only a few of which have been sufficiently examined to justify an interpretation. The changes are easily recognized, for the streams turn from broad valleys filled with drift deposits and pass into narrow ones, where they are now cutting into the rock floor. One of the most conspicuous instances of such a change is found in Owl Creek, which formerly discharged southward through the broad drift-filled valley traversed by the Baltimore and Ohio Railway between Mount Vernon and Newark, but which now turns east and soon enters a narrow gorge with rocky rapids, through which it passes to the Walhonding.

The glacial deposits have been transported down the valleys far beyond the limits of the ice sheet, and have filled them greatly. From Zanesville southward, where the stream is in a new course, the filling amounts to but 75 or 100 feet, but from that city northward it increases rapidly, soon reaching 200 feet, while at the present continental watershed, near the head of the Tuscarawas, it is fully 400 feet. Notwithstanding this greatly increased filling toward the north, the gradient of the streams is not high, the fall being less on the Tuscarawas than on the Scioto and Miami rivers. From the canal summit, near the head of the Tuscarawas, to the junction of the Tuscarawas and Walhonding there is a fall of about 3 feet per mile, and from the junction to the mouth of the Muskingum about 1½ feet per mile. On the Walhonding the descent is more rapid, as its headwaters, near Mansfield, are about 400 to 450 feet above the level of the stream at its junction with the Tuscarawas.

The effect of the glacial filling is extended into certain valleys which

[1] Bull. Dennison University, Granville, Ohio, Vol. VIII, 1894, part 2, pp. 35–62.
[2] Bull. Geol. Soc. America, Vol. VIII, December, 1896, pp. 7–13.

were not lines of discharge for the glacial waters. Thus on Wills Creek and its tributaries, and on the tributaries of the Tuscarawas which enter from the southeast, there are silt deposits which so fill the lower courses of the valleys as to give them a very slight fall. It has been noted that these streams are laboring at a great disadvantage because of the extremely low gradient. Precise measurements are not at hand, but it is known that in some cases they have long stretches in which the fall is but an inch or two per mile, and the average fall, except for a few miles at the sources of the streams, will scarcely exceed 1 foot per mile.

The run-off from the portion of this drainage basin above Zanesville has been carefully gaged at that city for the past nine years, gage readings having been taken four times per day. Capt. H. M. Chittenden, of the United States Army Engineers, has had the record carefully worked up from December 1, 1887, to November 30, 1895, and has found that the mean run-off for the eight years amounts to 13 inches per annum, or about 33 per cent of the rainfall. In the three driest years—1889, 1894, and 1895—it was reduced to 7¼ inches per annum, which is 22 per cent of the mean rainfall for those years. These results, together with diagrams showing curves for rainfall and run-off each year, are presented in his recent report to the Chief of Engineers.[1]

The following table taken from Captain Chittenden's report gives the monthly mean for the eight years and for the three dry years 1889, 1894, and 1895:

Table showing rainfall and run-off in the Muskingum drainage basin above Zanesville, Ohio.

Month.	Mean for eight years 1888-1895.		Mean for three dry years 1889, 1894, and 1895.	
	Rainfall.	Run-off.	Rainfall.	Run-off.
	Inches.	*Inches.*	*Inches.*	*Inches.*
December	2.34	0.821	2.37	0.910
January	3.27	1.605	3.24	1.521
February	3.34	2.529	1.80	1.241
March	2.85	1.907	1.93	1.104
April	2.69	1.274	2.15	0.739
May	4.33	1.426	3.02	0.371
June	4.42	0.870	3.26	0.349
July	3.85	0.467	3.21	0.296
August	3.25	0.338	3.13	0.148
September	3.22	0.488	3.56	0.140
October	2.87	0.502	1 97	0.105
November	3.22	0.778	3.44	0.334
Total	39.65	13.005	33.08	7.258
Percentage	33		22	

[1] Survey of the Miami and Erie Canal, etc., by Capt. Hiram M. Chittenden, Corps of Engineers, U. S. Army, House Doc. No. 278, Fifty-fourth Congress, first session, 1896, pp. 41-43.

The available water power on the main river from Zanesville to the mouth is restricted to the sites of the Government dams, ten in number, made for the purpose of affording slack-water navigation, and which embrace a fall of 103 feet. But a small portion of the power afforded by these dams is at present utilized. Professor Porter's report shows the utilized power of the Muskingum and tributaries in 1880 to have been 7,066 horsepower, of which only 1,165 horsepower were on the main stream.

BEAVER RIVER SYSTEM.

The Beaver River, formed by the junction of the Shenango and Mahoning rivers, although situated in Pennsylvania, affords a line of discharge for the portion of eastern Ohio drained by the Mahoning and some of the headwaters of the Shenango. Of the 3,000 square miles of its drainage area, about 1,200 square miles are in Ohio, and of this perhaps 1,000 square miles are tributary to the Mahoning.

The Mahoning leads northward from its source in Columbiana County to near Warren, Ohio, where it makes an abrupt turn to the southeast. From this bend the deeply drift-filled Grand River basin leads northward to Lake Erie. This basin, as noted above, apparently afforded a northward discharge in pre-Glacial times for a large part of the upper Ohio system aside from the Mahoning.[1] The old line of drainage of the upper Ohio followed the Ohio from Pittsburg to Beaver, Pennsylvania, and then followed the Beaver (reversed) to the junction of the Shenango and Mahoning. It then appears to have crossed the narrow neck of land between these streams to the Shenango at Harbor Bridge, Pennsylvania, and followed the Shenango (reversed) to Sharon, Pennsylvania, from which point it passed southwest through an abandoned valley, utilized by the Lake Shore and Michigan Southern and Erie railways, to Youngstown, Ohio, and thence northward along the Mahoning (reversed) to the Grand River basin. The present Mahoning below Youngstown crosses an old divide, but takes a much more direct course than that of the prelacial line.

The fall on the Mahoning from Alliance to the bend near Warren is about 150 feet in a distance of 40 miles. From the bend of the Mahoning to its junction with the Shenango the fall is about 100 feet in a distance of 35 miles. The fall of the Beaver from this junction to its mouth, a distance of 25 miles, is also about 100 feet. Of this fully 50 feet occurs in the lower 4 miles, leaving the remainder of its course a rather sluggish stream. The Shenango falls about 200 feet in 56 miles from Jamestown, Pennsylvania, to its junction with the Mahoning.

The lower course of Beaver River affords valuable water power, which has been largely utilized. The flow is estimated to reach a minimum of

[1] See P. Max Foshay, Am. Jour. Sci., November, 1890; T. C. Chamberlain and Frank Leverett, ibid., April, 1894; I. C. White, Am. Geologist, December, 1896.

300 feet per second in the low water of a dry year and 450 in the low water of an average year. There is thought to be available for ten months an average of 700 feet per second. Nearly 40 feet fall is available, without much detrimental influence from backwater on the Ohio.

The Mahoning, Shenango, Connoquenessing, and Neshannock each furnish water power, which has been extensively utilized, and smaller tributaries have also furnished power for a few mills. The Shenango and Neshannock drain districts in which the drift is gravelly and the flow regular. The Connoquenessing drainage basin is partly outside the glacial boundary, but is fed by numerous springs and thus rendered regular. The Mahoning drains a district with clayey drift, in which run-off is more irregular than in the other tributaries. Professor Porter reports, however, that it supplies power for 5 gristmills. Its tributaries also are reported to supply 5 gristmills. The Shenango, at the time of Professor Porter's report (1880), supplied 4 gristmills and its tributaries 5; the Neshannock supplied 2, and the Connoquenessing and tributaries supplied 4. In addition to gristmills, numerous sawmills, tanneries, or other establishments made use of water power.

TRIBUTARIES OF LAKE ERIE.

The portion of Ohio north of the continental divide, embracing an estimated area of 12,000 square miles, together with an area of about 1,000 square miles in northeastern Indiana, discharges its waters to Lake Erie. Attention has been called to the former northward discharge of much of the present Ohio system to the Lake Erie basin, an area several times as great as that of the present tributaries. The present water-parting between tributaries of Lake Erie and of the Ohio has its position largely determined by drift deposits, there being, as noted above, a system of moraines occupying much of this water-parting. There are probably but few points at which the present water parting is coincident with the preglacial water-parting.

The streams draining to Lake Erie are in several instances known as rivers, but such streams in other localities are usually termed creeks. In but three instances do these streams have a length exceeding 50 miles. Since they have their source in the continental divide, at elevations of 900 to 1,200 feet above tide, and the level of Lake Erie is but 573 feet, the fall is necessarily great. In the majority of them it averages not less than 10 feet per mile. The streams of northwestern Ohio and northeastern Indiana, however, because of their length and the low altitude of the divide in that region, have a much lower rate of fall, a rate not greatly different from that of tributaries of the Ohio. One of the streams, as indicated below, has notable falls, and several of them have small falls and rapids. The following table indicates the average rate of descent of the more important streams.

Table showing rate of descent of tributaries of Lake Erie.

Stream.	Altitude of source above tide.	Estimated length.	Fall per mile.
	Feet.	*Miles.*	*Feet.*
Conneaut Creek	1,080	40	12.67
Grand River	900	50	6.54
Chagrin River	1,200	35	17.9
Cuyahoga River (above falls)	1,200	48	4.5
Cuyahoga River (at falls)	985	2	110.0
Cuyahoga River (below falls)	765	35	5.5
Rocky River	1,100	30	17.6
Black River	1,100	50	10.5
Vermilion River	1,200	45	14.0
Huron River	1,100	40	13.2
Sandusky River	1,150	90	6.4
Maumee River	737	150	1.1
Auglaize River	1,000	74	4.4
St. Mary River	975	100	2.38
St. Joseph-of-the-Maumee River	1,050	100	3.13

Conneaut Creek.—Conneaut Creek finds its source in a moraine near Conneaut Lake, in Crawford County, Pennsylvania. It leads northward through a broad valley, described by Mr. Carll, of the Pennsylvania survey, as the Conneaut outlet, and which in preglacial times was the line of discharge for the middle portion of the Allegheny River drainage busin.[1] Upon reaching the low country on the border of Lake Erie the stream is diverted westward by a morainic ridge, whose outer border it follows into the State of Ohio until it finds a passage near Kingsville, which permits it to turn northward into the lake, though there is a slight diversion to the east, caused by a beach line. The preglacial line of discharge entered the Lake Erie basin in the northwestern corner of Pennsylvania. Its point of entrance is now completely filled by deposits of till. The stream encounters rock strata throughout much of its westward course, and is there flowing in a narrow gorge, strikingly in contrast with the broad, shallow valley of the old middle-Allegheny outlet. The headwater portions of the stream are fed by numerous springs, which give it a somewhat regular flow. No data have been obtained concerning the utilization of water power.

Grand River.—Grand River is a small stream draining the basin from which it receives its name (see p. 432). Its northward course, like that of Conneaut Creek, is through a former outlet of a much larger stream, and, like Conneaut Creek, it is diverted westward, near the bor-

[1] J. F. Carll, Second Geol Survey Pennsylvania, Rept. III, 1880, pp. 356-366; T. C. Chamberlin and Frank Leverett, Am. Jour, Sci., April, 1894.

der of Lake Erie, by a morainic ridge running parallel with the lake shore. This morainic ridge holds the stream in a westward course nearly to its mouth, at Painesville. The preglacial stream which discharged through the Grand River basin came to the present shore of Lake Erie a few miles west of Ashtabula, near the village of Geneva. Grand River, like Conneaut Creek, encounters rock strata throughout much of its westward course, and there flows in a narrow gorge, strikingly in contrast with the broad, shallow valley of the Grand River basin. This stream is subject to very low stages in seasons of drought, owing to the compact nature of the formations on its borders. Where flowing in the drift there is a compact silt, and where flowing in the rock an impervious shale, neither of which furnishes much water in seasons of drought. No data have been obtained concerning the utilization of water power.

Chagrin River.—Chagrin River has two headwater forks, each of which finds its source in marshes among the knolls of an interlobate moraine on the elevated upland east of the Grand River basin. The two streams join near Chagrin Falls, above which point the valleys are inconspicuous. At the falls there is a descent of a few feet over sandstone ledges. The stream then enters a preglacial channel which has been partially filled with drift. The name Chagrin River is said to have been applied to this stream because its valley was mistaken for that of the Cuyahoga by early surveyors, who upon discovering their mistake expressed their chagrin in this way. This old valley can scarcely have drained a large area, since the larger systems discharging through the Grand River basin and the Cuyahoga would have absorbed nearly all the drainage except a narrow strip lying between their trunk streams.

Cuyahoga River.—The present Cuyahoga River has its head near the source of the east fork of Chagrin River, on the uplands east of the Grand River basin, only a few miles from the shore of Lake Erie. It leads southwestward for nearly 50 miles, away from the lake, occupying a shallow valley bordered by marshes throughout much of its course, and having an average fall of but 4.5 feet per mile. It then makes a fall at the village of Cuyahoga Falls of 220 feet within a distance of 3 miles and enters a broad preglacial valley, which it follows northward to Lake Erie at Cleveland.

In this preglacial valley there is a heavy drift filling, both beneath the stream and on the borders of the valley. Wells in Cleveland indicate that the valley floor is about 400 feet below the mouth of the present stream. Silt deposits on the borders of the valley indicate that it was filled to a height of fully 200 feet above the present stream, or to within 100 feet of the level of the bordering uplands. From these data it appears that the preglacial valley was about 700 feet in depth. Its width was scarcely 2 miles, but being bordered at the brow of the bluffs by ledges of resistant sandstone, it has preserved a somewhat

narrow channel. As noted above, this valley may be the line of discharge for a large drainage basin embracing the greater part of southeastern Ohio and considerable portions of West Virginia and eastern Kentucky.

The following data concerning the flow at Cuyahoga Falls have been furnished by Prof. F. W. Claypole:

Discharge of Cuyahoga River at Cuyahoga Falls, Ohio.

Average discharge, about 195 cubic feet per second.

Maximum discharge, about 400 cubic feet per second; maintained for twenty-five or thirty days each year.

Minimum discharge, 65-100 cubic feet per second; maintained two to three months each year. The discharge becomes so reduced in summer, and often in winter, that the water power at mills is supplemented by steam.

Rocky River.—Rocky River has two forks, which unite near the town of Berea. These tributaries are mainly in drift-filled preglacial valleys, but the united stream northward from Berea is largely in a new course. It crosses the preglacial valley from west to east a short distance north of this city, as pointed out by Dr. D. T. Gould,[1] who has traced a preglacial valley from a point a short distance above Berea northward on the east side of that city to Lake Erie, which it enters a short distance west of the present mouth of the stream. Each of the forks has falls and rapids in passing over the Berea grit, those on the east fork being at the city of Berea and those on the west fork at the village of Olmsted Falls. The present channels of the streams are shallow above these falls and rapids, being but 25 to 40 feet in depth, but upon passing the outcrop of Berea grit the soft Cuyahoga shale is entered and a narrow canyon-like gorge 100 feet or more in average depth is excavated.

Black River.—Two streams with this name unite at the city of Elyria, and pass thence northward to the lake at Lorain. The eastern or main fork has its source on the borders of an extensive marsh near Lodi, and flows thence northward mainly through a drift-filled valley. At the city of Elyria it has falls nearly 40 feet in height which furnish power recently rehabilitated. The west fork heads in a moraine near the village of Nova and takes a course east of north, channeling a passage much of the way through rock strata, its course not being coincident with the preglacial drainage line. The united stream is mainly in a new course from Elyria to its mouth. Prof. A. A. Wright, of Oberlin, states that six mills have been in operation on the east and two on the west branch, which utilized water power for part of the year. Those on the west branch are discontinued, though one dam remains to impound water for Elyria waterworks. Some use is still made of water power on the east branch in Elyria, but the stream is not large enough at low-water stage to furnish much power.

[1] The Berea Advertiser, April 16, 1886.

Vermilion River.—This stream heads in the midst of the watershed series of moraines near Greenwich, and flows east of north mainly through a rock-bound postlacial valley. It drains a somewhat elevated sandstone district. Its channel is narrow throughout its course, being usually but 15 or 20 rods wide, and for a few miles near the mouth it is 100 to 150 feet in depth. Two mills, Brownhelm and Birmingham, use water power, supplemented by steam (A. A. Wright).

Huron River.—Huron River has its source in extensive marshes between moraines of the watershed series near New Haven. It drains a low district, underlain by shale, along the western border of the Berea grit. Its valley is shallow compared with that of the Vermilion, seldom exceeding 50 feet in depth. Professor Wright reports that this stream can not be used for supplying water power in any great amount, owing to its very low stage in seasons of drought, but thinks profitable use might be made in fall and spring.

Sandusky River.—Sandusky River is a larger, more widely branching stream than any of the tributaries of Lake Erie thus far discussed. It consists of a westward and a northward flowing portion. The westward flowing portion leads from the escarpment of Eocarboniferous sandstone near Crestline westward down the slope to the axis of the Scioto basin. Instead of turning south, as the neighboring streams do, to enter the Scioto River, it turns north, and flows down a gradual slope to Lake Erie. It enters Sandusky Bay at the western end. The valley of this river is small, being only 20 to 50 feet in depth and one-fourth mile or less in average width. It is generally cut into rock a few feet. No data concerning the use of water power have been obtained.

Maumee River.—The Maumee River system has the greater portion of its drainage area within the State of Ohio, but small portions are found in Indiana and Michigan. As indicated above, the drainage of this system was formerly southwestward to the Wabash, the northeastward outlet of Lake Erie being at that time occupied by the ice sheet. Upon the withdrawal of the ice sheet from the St. Lawrence basin the glacial lake which occupied the western end of the Lake Erie basin lowered itself to the level of new outlets that were formed and thus ceased to flow to the Wabash. The mouth of the old lake being near the point where the St. Mary and St. Joseph rivers had their discharge, and being higher than the portion of the basin toward the east and the portion of the outlet toward the west, there was a natural summit formed upon the withdrawal of the lake, from which the waters of the St. Joseph and St. Mary rivers were free to flow either to the east or to the west. By some accident of deposition or of slope the stream found it easier to turn eastward than to maintain its original course westward, and thus the Lake Erie drainage basin embraces these streams as well as those which have been formed in the old lake bottom or were tributary to the old lake.

The Maumee River has a length of about 150 miles and a fall of 164 feet, the source being 737 feet and the mouth 573 feet above tide. It is not itself a navigable stream, but is followed closely by the Wabash and Erie Canal, which for many years afforded a means of water transportation.

St. Mary River has its source in Shelby County, Ohio, at an elevation of about 975 feet above tide, or 238 feet above the level of its mouth. The length of the stream being about 100 miles, the average fall is scarcely 2½ feet per mile. The portion within the State of Indiana has a fall of but 18 feet in a distance of 35 or 40 miles, or about 6 inches per mile. It is, therefore, very sluggish in its lower course. The course of the river, both in Ohio and Indiana, is largely determined by a moraine which lies on its north border. The descent of the river corresponds closely to that of the plain in which it flows, and the stream has formed but a shallow channel, seldom more than 25 feet in depth.

The St. Joseph-of-the-Maumee has its source in southern Michigan and flows southwest across the northwestern corner of Ohio, entering Indiana about 35 miles above its mouth. Its length, like that of the St. Mary River, is about 100 miles. It has a more rapid fall, since its source is in a more elevated district, standing about 1,050 feet above tide. The portion in Indiana has a fall of nearly 2 feet per mile. The river flows throughout much of its course in a narrow plain between two morainic ridges, and its descent is determined by that of the plain. Its valley cuts only 25 to 50 feet into the plain and has very narrow bottoms. The stream has been well utilized for mill power, three mills having been constructed within the limits of Indiana.

The principal southern tributary of Maumee River in Ohio is the Auglaize River, which enters at Defiance. The relation of the course of this stream and of its principal tributaries to the morainic ridges may be seen by reference to the glacial map (Pl. XXXVI). It will be observed that the main stream and also two of its eastern tributaries, Hog Creek and Blanchard River, have their westward courses along the outer border of morainic ridges, while their northward courses and the courses of the smaller tributaries are directly away from the St. Mary moraine.

It should be noted also that Tiffin River, a northern tributary entering the Maumee at Defiance, follows the outer border of the Blanchard moraine, while its tributaries, like those of the Auglaize, lead away from the St. Mary moraine.

The drainage of the district lying between the Blanchard moraine and Lake Erie, in northwestern Ohio, is in lines flowing directly away from the moraine. A large part of the drainage is into the Maumee, but Portage Creek carries the drainage of a narrow belt directly to Lake Erie.

THE LAKE MICHIGAN SYSTEM.

There are two tributaries of Lake Michigan worthy of note which cross the northwestern part of Indiana. Of these the more important is the St. Joseph River, and the one of lesser importance is the Calumet.

St. Joseph River.—The St. Joseph River, although having a length of about 200 miles, flows for a distance of only 35 or 40 miles within the State of Indiana, its course being mainly within the State of Michigan. The former southwestward discharge of this river from South Bend into the Kankakee has already been discussed.

The portion of the stream in Indiana traverses a plain of gravel built up as an outwash from the ice sheet. It has cut a channel in this plain 40 or 50 feet in depth. The fall is sufficient to afford excellent water power, which has been extensively utilized at Elkhart and South Bend, as well as at Niles, Michigan.

There are several tributaries of the St. Joseph in northern Indiana which drain almost the entire area of Elkhart and Lagrange counties, considerable portions of Steuben and Noble counties, and a small portion of St. Joseph County. Of these tributaries, Elkhart and Pigeon rivers are the most important.

Elkhart River has a length of about 60 miles and a drainage basin of perhaps 500 square miles. Its source is in the great interlobate Erie-Saginaw moraine and near the border of Lagrange and Noble counties. About half its length is occupied in descending the northwestern slope of that moraine. It winds about greatly through a series of marshes and shallow lakes, inclosed by morainic hills, and makes most of its descent in passing from one marsh to another. Its lower portion is in a gravel plain on the outer southwestern border of one of the Saginaw moraines. It enters the St. Joseph at the city of Elkhart. The water power of Elkhart River has been utilized at several points in its lower course, and especially at Goshen and Elkhart. Mr. F. E. C. Hanks, of the Goshen Milling Company, estimates that at low stages in July and August only about 300 horsepower are available, but at ordinary stages there are two or three times that amount.

Pigeon River, a tributary entering the St. Joseph just north of the State line, flows throughout the greater part of its course within the State of Indiana. Its source is on the east side of the great interlobate morainic belt, in Cedar Lake, in the extreme northeast corner of Indiana. It flows for nearly 20 miles in a southwestward course, parallel with the moraine, and then turns abruptly northwestward through it. The moraine at this place is broken by a deep channel about 150 feet lower than the neighboring portions of its crest, which has the appearance of being produced by stream action. It is thought to have been formed by a stream issuing from the Erie ice lobe. That ice lobe appears to have persisted on the plain east of the interlobate moraine until the Saginaw lobe had withdrawn from northern Indiana, thus preventing

the drainage from the east slope of the moraine from passing to the Maumee basin and forcing it across the moraine into the St. Joseph River. Upon reaching the northwest border of the interlobate moraine, the stream enters a gravel plain formed along the outer border of a Saginaw moraine and follows this gravel plain to its mouth. In this portion of its course it receives several tributaries from the south, but has none whatever from the north, thus presenting a very one-sided development. In its headwater portion east from the interlobate moraine the stream has a shallow channel cut in the drift plain through which it flows. In its course through the moraine it passes through several marshes or shallow lakes occupying the channel of its broader predecessor. In the gravel plain it has a well-defined but small channel cut to a depth of 25 to 40 feet.

Immediately north of Pigeon River is another stream having a nearly parallel course. Though commonly called Crooked Creek, the name for a portion of its course is Fawn River. It is the outlet for several of the lakes inclosed among the morainic ridges of northern Steuben County. It is deflected into the State of Michigan by the Saginaw moraine that lies along the north border of Pigeon River, but soon passes through that moraine and enters the gravel plain through which the Pigeon River flows. In the lower 25 or 30 miles of their course these rivers are but 1 to 4 miles apart, but maintain separate channels to the St. Joseph River.

Calumet River.—Calumet River drains a narrow strip between Lake Michigan and the Valparaiso moraine from the vicinity of Michigan City westward to the edge of Illinois. It has a length of fully 100 miles, but its drainage basin averages less than 10 miles in width. Within a few miles of its source it reaches a level only 40 or 50 feet above the lake, and has therefore throughout the greater part of its course a very sluggish current. At Blue Island, Illinois, it reaches a level no higher than the high stages of Lake Michigan. The region which it traverses contains a series of marshes and sand ridges, which it drains very inadequately.

ILLINOIS RIVER SYSTEM.

Kankakee River.—One of the principal headwaters of the Illinois River, the Kankakee, flows for nearly 100 miles within the State of Illinois. At its source, near South Bend, the marshy channel through which the St. Joseph River formerly flowed stands about 705 to 710 feet above tide. At the State line the elevation of the river is 620 feet above tide. The rate of descent is therefore nearly 1 foot per mile. But, on account of the great breadth and shallow depth of the stream, this fall is inadequate to give a strong current. Extensive tracts along the course of the stream, as well as on the borders, still remain in a marshy condition, and the high grass greatly obstructs the flow of

the water. By systematic ditching this marsh may be drained, and probably with profitable returns for the outlay.

Some of the eastern tributaries in St. Joseph and Marshall counties have their sources in a moderately elevated upland and have developed good drainage lines, as have also tributaries on the north border, which head in the Valparaiso moraine described above. But from Marshall County westward, along the south side of the Kankakee, there is no relief sufficient to develop drainage lines for a distance of 20 miles or more back from the river. By means of artificial ditches, however, a large amount of land in this region has been brought into a condition suitable for agriculture. Where not drained in this manner the region is a forbidding waste of marshes and sand ridges.

The Iroquois River, a southern tributary of the Kankakee, entering near the city of Kankakee, Illinois, has its headwaters in northwestern Indiana. Its course leads westward from eastern Jasper County through a plain having sufficient descent to give it fair drainage, there being a fall of 25 or 30 feet in the 30 miles between Rensselaer and the State line.

LAKES.

The State of Ohio has an important resource in Lake Erie, with its several excellent harbors. Extensive commerce is carried on from Toledo, Sandusky, Cleveland, and Ashtabula, which extends to the mining regions of the north as well as to the Atlantic seaboard.

The State of Indiana, although bordering upon Lake Michigan, has but one harbor, that at Michigan City. The great amount of sand drifted into the head of the lake in northerly storms makes the maintenance of a harbor difficult. An important harbor is, however, maintained.

The northern part of Indiana and parts of northern Ohio carry small lakes occupying depressions in the glacial drift. These lakes seldom exceed 1 or 2 square miles in area, and are usually but a fraction of a square mile. In a few cases, however, an area of 5 or 6 square miles is reached. In Indiana these lakes are found mainly in the great interlobate moraine, which traverses Steuben, Lagrange, Noble, Whitley, Kosciusko, and Fulton counties. In addition to this system of lakes there are several along the Valparaiso moraine in Laporte, Porter, and Lake counties and along the Maxinkuckee moraine in Marshall and St. Joseph counties. There is also a lake of some importance in Stark County (Cedar Lake), which does not lie in a morainic belt. In addition to these morainic lakes there are lake-like expansions of the Kankakee River, as at Mud Lake and English Lake. There are also portions of the Kankakee marsh which never become dry. The greater part of the surface of Indiana is entirely free from lakes, though in wet seasons marshes and ponds are formed in the poorly drained tracts. The extent of these marshes and ponds has been greatly reduced by cultivation and systematic ditching and underdrainage.

In Ohio several lakes are found in an interlobate moraine west of the Grand River basin in Geauga and Portage counties and a few in the midst of moraines in Summit, Stark, Medina, Wayne, and Ashland counties. These lakes are seldom more than a square mile in area and usually occupy but a few acres.

In western Ohio there are several artificial lakes, formed as reservoirs for feeding the canals. The Lewiston reservoir, situated near the head of the Great Miami River, in Logan County; Grand reservoir, situated near the head of a tributary of the Wabash River, in Auglaize and Mercer counties; Loramie reservoir, on Loramie Creek, in Shelby County; and Six Mile reservoir, on a tributary of the Maumee River, in Paulding County, each cover an area of several square miles. Their sites were originally heavily timbered plains, and have been covered by water by the erection of large dams across the course of streams which traverse these plains. Another artificial lake, Licking reservoir, was made in central Ohio to feed the Ohio Canal, connecting the Ohio at Portsmouth with Lake Erie at Cleveland.

In Ohio, as in Indiana, there are many ponds and marshes in wet seasons which become dry in seasons of drought. Cultivation and ditching have greatly reduced the extent of these poorly drained tracts.

Aside from the classes of lakes already discussed there are a few small lakes or ponds found in the sink holes of the limestone districts of southern Indiana; one of these—Palmyra Lake, in Harrison County—covers several acres and is reported to have a depth of 14 feet. Lakes of this class are usually formed by the natural obstruction of the outlet, but in a few cases have been formed artificially by filling the hole in the bottom of the basin.

There are also small lakes formed in abandoned channels of streams. The Ohio and Wabash and other streams in southwestern Indiana furnish several examples. These may in some cases be drained, but are often too low to admit of complete drainage, their bottoms being nearly on a level with the beds of the neighboring streams.

The small lakes of northern Indiana and northeastern Ohio, and also the reservoirs of Ohio, afford an excellent habitat for fish. A report on the lampreys and fishes of Indiana, by Prof. O. P. Hay, recently published by the Indiana Geological Survey, describes about 150 different species, many of which are found in these lakes.[1]

Considerable attention has been given the lakes of Indiana by the State geological survey and State university, and also by private corporations, with a view to determining their resources. In the report of the geological survey for 1873, Dr. G. M. Levette gives a general description, and in the report for 1875 a detailed discussion of the features, together with soundings, of several of the larger lakes. Dr. David Starr Jordon has an extended discussion of the cisco of Lake Tippecanoe in the geological report for 1874. Messrs. W. H. Thompson and S. E. Lee

[1] Nineteenth Ann. Rept. Indiana Geol. Survey, 1894, pp. 146-296.

have a detailed description of Lake Maxinkuckee and brief references to other lakes of Marshall County in the geological report for 1885–86. Dr. C. R. Dryer has presented, in the geological reports published in 1891 and 1893, a detailed description of the lakes of Steuben, Whitley, Noble, and Lagrange counties, giving soundings and notes as to character of the lake bottoms as well as reports upon the fauna. The most detailed study of these lakes yet attempted is that of Turkey Lake in Kosciusko County, carried on by Mr. C. H. Eigenmann, under the auspices of the State university. A report has already appeared in the Proceedings of the Indiana Academy of Sciences for 1895–96, but the investigations are to be continued for a period of years. It will involve a complete biological classification, as well as temperature tests and other matters of value in determining the conditions for fish culture. The equable conditions furnished by these lakes and reservoirs, compared with those of streams, promise to afford profitable fields for fish culture. In some cases the enemies of food-fish may interfere with such culture, but carefully conducted investigations and experiments will no doubt furnish a sufficient knowledge of the conditions to render the culture of a number of species of fish profitable.

The beauty of scenery which these lakes and the surrounding morainic hills afford renders them very attractive resorts for summer homes, and already many of them have their banks dotted with cottages.

UNDERGROUND WATERS.

GENERAL STATEMENT.

The following classification of underground waters seems to the writer to be based upon clear distinctions, and to include the most important phases or classes of underground distribution to be found in the region under discussion. In nearly all cases it is not difficult to decide to which class a given water should be referred. The word "artesian" is avoided, since there is much difference of opinion concerning the scope of its application, some writers maintaining that it should be restricted to deep wells which overflow, others to wells which overflow whether deep or shallow, while others maintain that the overflow is a secondary matter, and include under this head all wells having strong hydrostatic pressure whether they be flowing or nonflowing.

Class 1. Ground water supplied by direct percolation of the rainfall into the soil and substrata, and subject to but little lateral transmission and little hydrostatic pressure. The water level rises and falls with the degree of saturation by rains.

Class 2. Waters in close association with streams, as in valley bottoms, in which lateral transmission is great and hydrostatic pressure is small. It differs from the former class not only in the great lateral transmission, but also in being fed partly by stream percolation. The level rises and falls with that of the neighboring streams. This

class should perhaps include the waters of sand plains and gravel plains which have no surface streams traversing them, for waters in such plains usually have great lateral transmission and but little hydrostatic pressure.

Class 3. Water included in porous beds of glacial drift or other nonindurated formation lying beneath impervious beds but without strong hydrostatic pressure. Such water is supplied from more or less distant absorption areas and is less directly influenced by rainfall than the preceding classes.

Class 4. Water with strong hydrostatic pressure included in porous beds of glacial drift or of alluvium. This affords many flowing wells and also wells in which water rises nearly to the surface.

Class 5. Streams in caves and subterranean passages in the rock, fed by sink holes and brooks, and also by direct percolation from ground water.

Class 6. Rock water with little current and slight hydrostatic pressure.

Class 7. Rock water under strong hydrostatic pressure. This includes not only waters which overflow when tapped, but also waters which rise nearly to the surface.

GROUND-WATER WELLS.

Wells of this class are ordinarily called surface or seep wells, and the local source of supply is thus recognized. The level of the water in these wells is about the same as in bordering formations, and rises and falls with the fluctuations of the ground water. In wet seasons the water stands near the top of the well, but in seasons of drought it may sink to a considerable depth.

Throughout the glaciated portions of Ohio and Indiana the drift is usually sufficiently thick and pervious to absorb rainfall in such amount as to furnish the surface or seep wells, but in a few places the drift is almost wanting, and the rainfall is directly absorbed by the underlying rock. If a well from the rock derives its supply by percolation from the soil or surface deposits on its immediate borders it seems legitimate to include it in this class, though there is perhaps an advantage in restricting this class of wells to the nonindurated formations and throwing the shallow wells in rock into class 6. In the unglaciated portions of the State the shallow wells, except in valleys filled deeply with alluvium or glacial gravel, are obtained from the rock, there being very seldom much water in the residuary clay that mantles the rock.

As the surface formations vary greatly in their capacity to absorb rainfall, the strength of wells in them may be expected to vary also. Wells in gravelly or sandy drift are stronger than those in bowlder clay or in the lacustrine or other silts. The bowlder clay or till shows great local differences in texture, varying from an oily clay without joints to a coarse-textured clay, or a clay with many fissures filled in with

sandy or gravelly material. A well of considerable strength may be obtained where a series of fissures lead into it and contribute the water they have absorbed. Bowlder clay is often intimately associated with deposits of sand or gravel. If such deposits are of limited extent and completely inclosed by bowlder clay they are of value only in extending the reservoir beyond the limits of the well; but if of great extent they usually furnish strong and lasting wells. Observations made by Prof. F. H. King, of the Wisconsin Agricultural Experiment Station, have shown that a well which drains the strata for but a short distance in wet seasons may greatly extend its drainage area in seasons of drought.

Both in Indiana and Ohio bowlder clay is by far the most widespread source of supply for ground-water wells, and such wells are often exhausted in seasons of drought. The plains between moraines have, as a rule, more continuous sheets of bowlder clay at their surface than the morainic belts, for the latter frequently are made up largely of gravelly deposits. The flatness of surface on these plains favors the filling of wells in wet seasons, and a failure to obtain a well is comparatively rare, whereas the undulating surface of the moraines is unfavorable to such filling, and shallow wells are often unsuccessful. On the whole, however, the moraines afford as strong shallow wells as the plains, for they gain in coarseness of material as much as they lose in undulation of surface. The moraines of knob-and-basin type are usually more gravelly than those of the smooth ridge type and afford a correspondingly larger number of strong wells.

There are a few plains in which the drift is so coarse as to afford large supplies of water. Perhaps the most extensive of these plains is found in Marshall and northern Kosciusko counties, Indiana, but western Shelby and eastern Johnson counties carry also an extensive gravelly plain. In Ohio the most conspicuous gravelly plain noted is that on the borders of the Scioto from Columbus south to Chillicothe. This plain extends out several miles from the river in the vicinity of Circleville. Near Newark there are plains covering perhaps 25 or 30 square miles in which the drift is largely of gravelly constitution. There are also similar plains northwest of Mount Vernon covering several square miles. Much of Clark, northwestern Greene, and eastern Montgomery counties carry a gravelly drift both on moraines and plains, and this gravelly drift leads down the broad valleys of the Mad and Miami rivers.

The number of ground-water wells in these States is far greater than that of all other wells combined. If the unglaciated portions of the State are excluded, there are probably twenty-five ground-water wells for every deeper well, whether in drift or in rock. In the 60,000 square miles of glaciated territory within these States there are estimated to be not fewer than fifteen ground-water wells for every square mile.

The value of the wells is not so much in the quantity of water furnished as in its ready accessibility.

Deeper wells are gradually supplanting ground-water wells in localities where the latter are liable to fail in seasons of drought, and also where surface contamination is suspected. The ordinary ground-water well is but 10 to 20 feet in depth. If on ground that is readily pervious, there is danger of locating the well too near sources of contamination, such as cesspools and manure heaps. Examples of such risk are found not only in villages where wells are necessarily located at only short distances from sources of contamination, but also in rural districts, where there is no need for such crowding. Some danger arises from the use of shallow wells in clay, for the clay often opens large fissures in dry seasons, in which filth accumulates or is washed when showers occur. On another page observations made by Hon. M. C. Read, of Hudson, Ohio, are presented, which show that these fissures afford great opportunity for surface contamination. (See p. 548.) The abandonment of polluted shallow wells has hardly kept pace with the knowledge of danger from their use, and such foolhardiness can scarcely be justified. This class of wells is not likely to be entirely superseded by deeper wells, for in many localities the best as well as most convenient supply is from this source. Their use should be guarded by the most watchful attention to the sanitary conditions and to the character of the water, and when pollution is detected there should be prompt discontinuance of the use, or, if no better water can be obtained, the water used for drinking should be properly boiled.

It is quite generally believed by old settlers that the shallow wells are becoming weaker and permanently lower, but in the absence of statistics only the probable influence of settlement upon such wells can be considered. The effect of settlement has been to afford better surface drainage by opening ditches and removing obstructions, and thus to lessen the amount of saturation. Cultivation of fields, leading as it usually does to a more rapid escape of water over the surface, also tends to lessen the degree of saturation. A somewhat reduced supply to shallow wells and a more frequent failure of such wells than in the days of early settlement are therefore to be expected.

The effects of the droughts of 1894 and 1895 upon ground-water wells are quite generally reported to be more severe than those of any other drought since the settlement of these States. A large number of wells 10 to 20 feet in depth became exhausted for the first time in their history. The level of ground water appears to have been generally lowered in bowlder clay to a depth of 10 feet or more below the surface. Such a lowering requires a long period of rain to restore the ground water, and though the rainfall of 1896 has been greater than in the preceding two years, many wells remain weak compared to their strength prior to the drought.

SHALLOW WELLS IN VALLEYS.

In the valleys of nearly all the large streams of Indiana and Ohio there are deposits of either glacial gravel and sand or of alluvium, which fill with water to the level of the surface of the stream. When the streams are at a low stage, the level of water in these wells usually sinks to a corresponding level. In some valleys, however, the streams extend below the level of porous beds into bowlder clay or rock, and the wells there are largely independent of the streams, being formed, as in deep wells on the upland, either in beds of gravel beneath the bowlder clay or in the rock. It is only wells of the former class that are here considered. The depth of this class of wells varies with the height of the well mouth above the stream. In most valleys the terraces underlain by alluvium or porous beds stand but 20 or 30 feet, or even less, above the stream. In the Ohio Valley, however, their height is seldom less than 50 feet, and occasionally reaches 100 to 120 feet above the low-water stage. The average altitude of the bottoms is probably fully 60 feet above the low stage. It is found that wells on the higher terraces as well as those on the lower must usually be sunk to river level to obtain a permanent supply.

This class of wells, like the shallow ground-water wells of the uplands, may become contaminated if care is not taken in their location. The flow of the underground water in valleys is usually from the bluff toward the stream and also down the valley. Wells should, if possible, be located on the upland side of cesspools, barnyards, or other sources of contamination. In cities or villages where waterworks are constructed, good water may usually be obtained by sinking infiltration wells on the upstream side of the town. Several cities along the Ohio, in West Virginia, Ohio, and Kentucky, have introduced a system of wells on bars in the river, which are cemented at top so that when the stream is high enough to cover the well mouth the water must enter from the bottom of the well at depths of 5 to 10 feet below the river bed. In the tables of city water supply given below the use of infiltration wells is indicated, and also the use of shallow wells in valleys. Where no waterworks system has been introduced, the wells in cities and villages located in valleys often are contaminated, and the speedy abandonment of private wells seems a necessity. Cisterns filled with rain water from roofs of dwellings are frequently used in such villages and furnish water of fair quality if properly filtered.

DRIFT WELLS WITH WIDE OR REMOTE ABSORPTION AREAS.

In the classes of wells just discussed the water supply is derived from the ground immediately surrounding the well mouth, or is liable to receive a part of its supply from the immediate border. In the class of wells now to be discussed the supply depends scarcely at all

upon the ground around the well mouth. The wells are usually so deep that no water gains access to them from this source. Commonly their supply is derived from beds of gravel or sand which are interbedded with the sheets of bowlder clay or till. They are supposed to be fed, like the water supplies found in the rock strata, from surface outcrops of the water-filled bed or through joints or other openings in the overlying drift sheet. In this discussion the wells in which a strong hydrostatic pressure occurs are not considered, since they form a separate class discussed below. There is usually, however, a decided rise in the water above the level at which it enters the well. But a few instances have been reported where a sheet of water has been found beneath bowlder clay that does not show a perceptible rise in the wells.

Wells of this class are represented very widely in the glaciated portions of Indiana and Ohio. In Indiana they may be found over the greater part of the State north of the latitude of Indianapolis and for 30 or 40 miles south of that latitude, where they supplant to considerable extent the use of shallow wells. There are, however, small areas along the Wabash Valley and its south border, and also in Jasper, Pulaski, and White counties, where the rock is struck at slight depths, as may be seen by reference to the accompanying map (Pl. XXXVII). In very few localities in northern Indiana have deep wells in the drift failed to obtain an abundance of water. It is often necessary, however, to sink to depths of 150 or 200 feet. Usually tubular borings 4 to 6 inches in diameter are made, and unless a well is found to yield at least 4 gallons per minute it is not considered sufficient for the demands made on such wells.

In southern Indiana, even where drift covered, the rock is usually encountered at depths of 20 to 30 feet or less. The wells in the drift are, therefore, usually ground-water wells. On lowland tracts and along morainic ridges, however, wells 50 to 100 feet in depth are often obtained without entering the rock.

In Ohio thick deposits of drift prevail less widely than in the northern half of Indiana. A few counties in the northwest corner of the State have a deposit exceeding 100 feet in average thickness, and a belt with similar thickness leads from west to east across the middle portion of western Ohio and thence southeastward to the Scioto basin, south of Columbus. With these exceptions the thick drift of the State is largely confined to valleys or lowland tracts which were probably occupied by streams in pre-Glacial times. Along the morainic ridges, however, there is usually about 100 feet of drift. In these regions of thick drift in Ohio, as in Indiana, deep wells are obtained in the drift, and failures are rare.

In the greater part of northern Ohio and also in the drift-covered portion of southern Ohio, outside the limits of the thick drift above outlined, it is often possible to obtain wells of this class at depths of 50 to 75 feet, or even less. There is, however, so much of this area in

which rock is encountered at less than 50 feet that the average value of deep drift wells is not so great.

Wells of this class are of inestimable value to the many villages and cities where they may be obtained and to the stock raisers in the rural districts. The quality of water is the best to be found at any horizon, for there is freedom from the contamination to which surface water and water from shallow wells is liable, and there are also very few wells in which the mineral ingredients are at all objectionable. The water is moderately hard and usually slightly chalybeate. The average depth of these wells probably does not exceed 75 to 100 feet, but even where it is necessary to sink a well to a depth of 200 feet or more, the excellent quality and large quantity of the water usually justify the outlay.

DRIFT WELLS WITH STRONG HYDROSTATIC PRESSURE.

Wells in the drift having strong hydrostatic pressure are widely distributed in Indiana and Ohio, but they are found usually either on the slopes of moraines or along valleys or in basins in which there is a thick filling of drift. The source of supply and cause for strong pressure are usually readily found. When on the slope of a morainic ridge, the water appears to be derived from porous beds exposed in the moraine or on elevated tracts outside of it. It is found that the sheets of drift often have an imbricate arrangement, the later sheets lapping over the earlier ones and burying beds of sand or gravel which have been deposited on the earlier sheets. Where the ice was advancing up a slope its sheets of drift outcrop on the higher parts of the slope and dip toward the lower parts. If, therefore, water is absorbed in porous beds outcropping on the higher portions of the slope, either along a moraine or in elevated districts outside, it may be expected to pass down the slope and yield wells with strong hydrostatic pressure wherever tapped. Flowing wells obtained in valleys or in basins probably are supplied in most cases by absorption on the borders of the valley or basin.

In Indiana wells are found to have a strong hydrostatic pressure and to occasionally overflow on either slope of the great interlobate moraine which stretches from the northeast corner of the State southwestward to the vicinity of Rochester. The high hydrostatic pressure is maintained for a considerable distance to the northwest from the moraine, in Kosciusko, Marshall, and St. Joseph counties, producing flows at Plymouth and other points.

On the northwest face of the Valparaiso moraine, in Laporte, Porter, and Lake counties, wells have a strong hydrostatic pressure, and occasionally overflow. The absorption area is probably mainly in the moraine, but may perhaps include the Kankakee marsh outside.

Among the drift ridges in Benton County, in western Indiana, adjacent to the flowing-well district of Iroquois County, Illinois, the wells have a strong hydrostatic pressure. This flowing-well district, as

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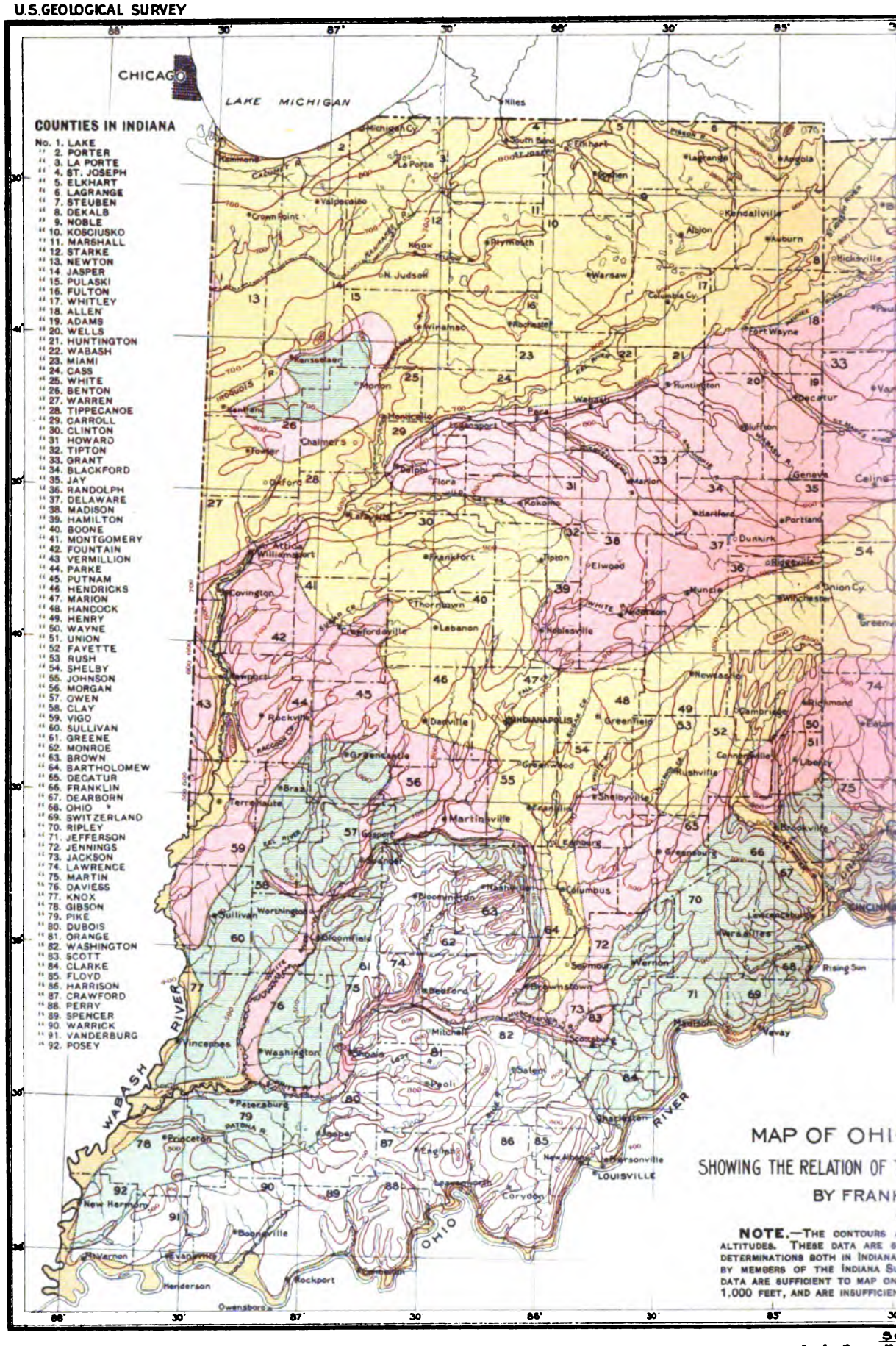

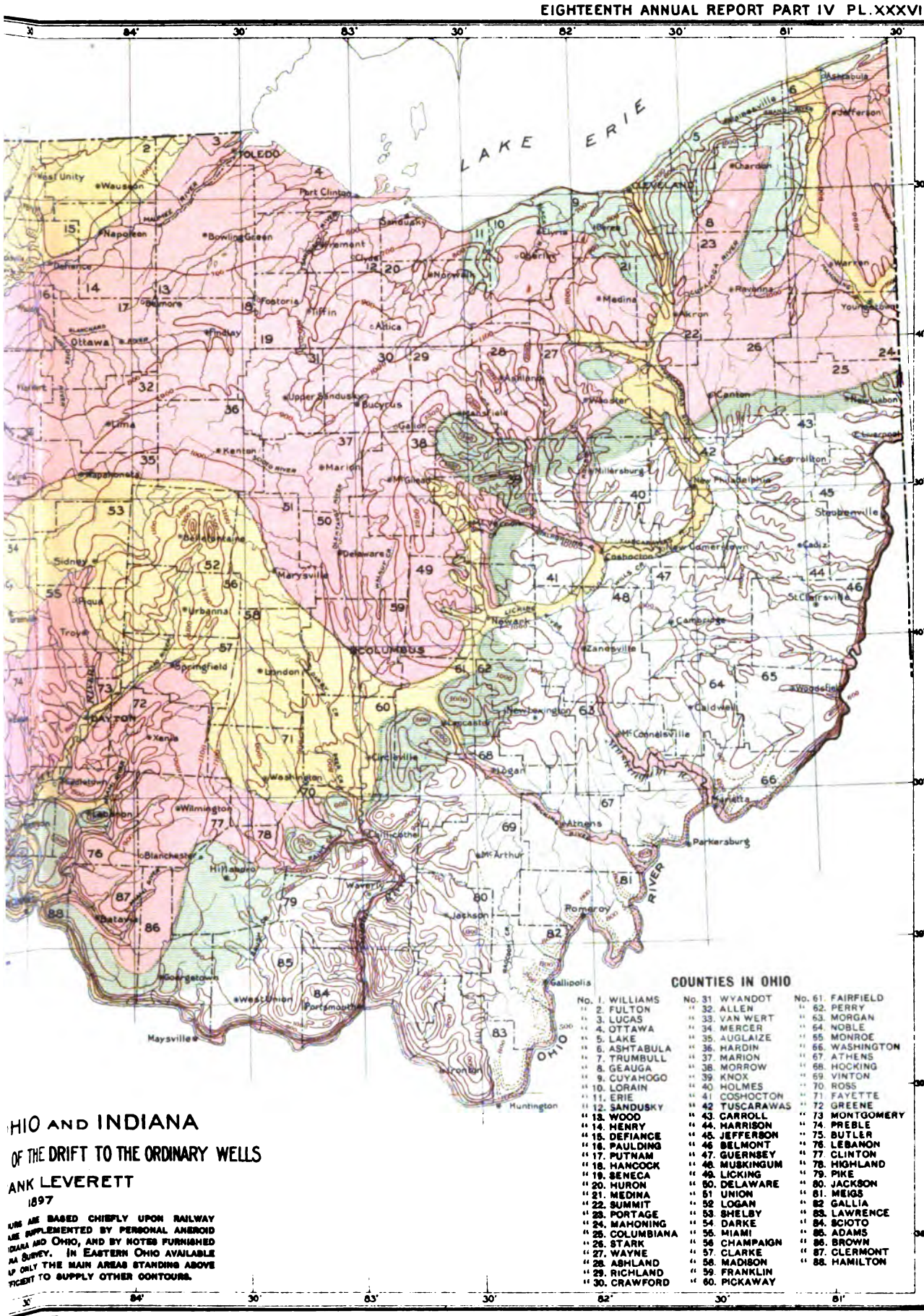
LAKE ERIE
TOLEDO
CLEVELAND
COLUMBUS
DAYTON
OHIO RIVER
Ashtabula
Jefferson
Chardon
Warren
Youngstown
Ravenna
Akron
Medina
Elyria
Lorain
Sandusky
Norwalk
Port Clinton
Fremont
Bowling Green
Napoleon
Defiance
Wauseon
West Unity
Fostoria
Tiffin
Findlay
Ottawa
Hicksville
Lima
Upper Sandusky
Bucyrus
Galion
Mansfield
Ashland
Wooster
Canton
New Lisbon
Steubenville
Cadiz
Carrollton
New Philadelphia
Millersburg
Coshocton
New Comerstown
St Clairsville
Cambridge
Zanesville
Newark
Lancaster
Logan
Chillicothe
Circleville
Washington
Wilmington
Hillsboro
Blanchester
Batavia
Georgetown
West Union
Portsmouth
Maysville
Ironton
Huntington
Gallipolis
Pomeroy
Jackson
Athens
Marietta
Parkersburg
McArthur
Caldwell
McConnelsville
Woodsfield
Newbetington
Kenton
Marion
Mt Gilead
Delaware
Marysville
Urbanna
Springfield
London
Xenia
Troy
Piqua
Sidney
Bellefontaine
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Ottawa
Hicksville
Lima

shown in a paper in the Seventeenth Annual Report, Part II, is apparently supplied from the water absorbed on the moraines which encircle the district on the southeast, south, and southwest.

Along the Iroquois River, from the vicinity of Rensselaer westward, flowing wells may be obtained which are apparently fed by water absorbed in the sandy districts near the head of the Iroquois. In these sandy districts the rock is encountered at a much higher altitude than in the flowing well district to the west, and the drift beds apparently have a westward dip, in correspondence with the decreasing altitude of the rock surface.

A few flowing wells have been obtained on the slopes of an elevated tract of drift in Clinton, Boone, Tipton, and Hamilton counties, which are apparently fed by water absorbed on the higher parts of this drift area.

Farther south, in the vicinity of Danville, Indiana, there are flowing wells which apparently have their absorption areas in the morainic tracts immediately to the west.

In eastern Indiana, on the slopes of the somewhat elevated tract which has its culmination in southern Randolph County, numerous flowing wells have been obtained along valleys, and wells on the bordering upland have strong hydrostatic pressure. The absorption area is readily found in the high part of the dome on whose slopes they occur.

A conspicuous instance of flowing wells along a valley is found in the case of the St. Joseph River. The city water supplies of South Bend and Elkhart are obtained from wells of this class. There is considerable hydrostatic pressure in wells between these cities, and a few overflow.

Another valley tract yielding numerous flowing wells is that of Flatrock Valley, in Rush County, from Rushville northward to Raleigh. The city of Rushville obtains the supply for waterworks from this source.

Along the Mississinewa Valley there are occasional flowing wells, one of which, at Marion, supplies a considerable portion of water for the waterworks. In the Salamonie Valley also, near Warren, several flowing wells have been obtained. These, however, in some cases enter rock.

In the valley of Treaty Creek, a small tributary of the Wabash in Wabash County, a series of flowing wells have been obtained which supply the waterworks of the city of Wabash.

The water in the flowing wells is usually slightly chalybeate, but this is also a characteristic of most of the deep drift wells, irrespective of hydrostatic pressure.

The wells are of various depths, some being but 12 to 20 feet, while others exceed 200 feet. They are usually obtained in beds of gravel

beneath sheets of till or of other very compact clay, as at South Bend. In a few instances the head is as great as 30 feet above the surface, but as a rule the flow ceases at a height of 10 feet or less. The accompanying table sets forth the location and depth of some of the strongest flowing wells. Further data will be given in a detailed discussion of the wells of Indiana which is to be published soon as one of the Water-Supply and Irrigation Papers. It will be observed that at certain localities the depth of the wells varies greatly. In such cases the flow begins at the least depth mentioned and usually becomes stronger at greater depths.

Table of flowing wells from drift in Indiana.

	Feet.
Northern Lake County, several wells	60–100
Northern Porter County, several wells	60–200
Northwestern Laporte County, several wells	60–250
South Bend waterworks, many wells	100–125
Elkhart, several wells	30–120
Near North Liberty, a few wells	45– 70
Teegarden and vicinity, many wells	40–100
Plymouth waterworks, several wells	40– 50
Lake Maxinkuckee, many wells	20– 75+
Warsaw waterworks, several wells	120±
Columbia City and vicinity, several wells	50–225
North Manchester waterworks, etc., several wells	50–100
Wabash waterworks, several wells	42– 55
Iroquois Valley, many wells	30–120
Oxford, one well	55
Templeton, one well	300
Flora, several wells	12– 47
Frankfort, several wells	15– 65
Danville waterworks, several wells	110
Greenfield and vicinity, several wells	150±
Newcastle waterworks, several wells	90–240
Moreland, one well	90
Near Liberty, two or more	40±
Raleigh, several wells	65–106
Rushville, many wells	14– 75
Middletown waterworks, etc., several wells	100±
Franklin, several wells	30– 90
Martinsville, several wells	40– 75
Northeastern Allen County, several wells (Dryer)	35– 45

In Ohio flowing wells are found as frequently as in Indiana, and in similar situations. Those in connection with moraines find conspicuous illustrations in the northwestern counties of the State, and also on either side of the elevated tract in the west-central part of the State. In several lowlands flowing wells of great strength have been found. Those at Mount Vernon and Mansfield are adequate to supply the waterworks. The wells of this class in Ohio will be discussed more at length by Dr. Edward Orton, in a bulletin for this Survey.

SUBTERRANEAN DRAINAGE LINES.

It is probable that there is movement in all underground waters, but the movement seldom is sufficiently rapid to be noticeable, and in many cases requires instrumental aid for its detection. In rocks not broken by fissures, such as sandstones and sandy shales, the transmission is apparently that of a slow current varying in rapidity with the texture of the rock, the slope of the bed, and the hydrostatic pressure. In fissured rocks, such as limestones and certain shales, the movement of water is chiefly through fissures and often assumes the force of a stream or line of surface drainage. In certain very soluble limestones the underground water has dissolved the rock and formed great caverns in which it flows with as much freedom as in surface streams. Indeed, surface streams of considerable size may be completely diverted into underground passages, forming so-called "lost rivers." It is only the last class of subterranean drainage that is here considered, for the other classes are considered under other heads.

Several kinds of limestone have caverns, but by far the most cavernous one of this region is the St. Louis limestone, and it is in this formation that the notable caves with their lines of subterranean drainage are developed. The St. Louis limestone outcrops in a narrow belt in Indiana leading from the Ohio River, in southern Harrison County, west of north, crossing East White River near Mitchell and White River near Spencer. It continues much farther north, but is largely concealed by drift. Caves have, however, been discoverd in it as far north as Greencastle. Where not covered by the drift, sink holes abound and surface drainage lines are very imperfect. The main drainage lines which cross this region have channels opened on the surface, but very few tributaries have a surface channel opened. There are many strong springs at points where the subterranean passages of tributaries open into the main drainage lines, springs which are adequate in some cases to run a mill or to supply a town. Thus Harrison Spring, a few miles west of Corydon, as noted above, has sufficient force to run both a gristmill and a sawmill. A cave spring near Salem supplies the waterworks of that city. One conspicuous instance of the diversion of a surface stream into a subterranean passage is found in Lost River, which disappears for a few miles in the vicinity of Orangeville and finds passage "in a complex system of mains and leads." In heavy freshets the stream can not be entirely absorbed by the subterranean channel and it then flows on the surface through the midst of a forest. Stampers Creek, a small stream in the same locality, is so completely absorbed that it has no surface channel opened beyond the sink. These subterranean streams and the caves of southern Indiana have long been known to geologists, and are described in considerable detail in the Geology of Indiana.[1]

[1]See Geology of Indiana, 1859, pp. 149-158, map p. 361; 1872, pp. 145-182; 1873, pp. 280-308; 1875, pp. 208, 209, 224-226, 1878, pp. 292-294, 306-309, 456-510, 1883, pp. 78, 79; 1884, pp. 73-75; 1886, pp. 151, 152; 1897, pp. 121-212.

The Burlington and Keokuk limestone of Eocarboniferous age and the Niagara limestone of Upper Silurian age usually afford fair transmission for subterranean streams. Where these limestones outcrop along valleys copious springs often occur, which testify to the strength of subterranean drainage. Occasionally a cave has been found of sufficient size to admit of exploration, though small compared with the caves St. Louis limestone.

ROCK WELLS WITH SLIGHT HYDROSTATIC PRESSURE.

In places where the drift does not furnish an abundance of water, either because of its slight depth or its compactness of texture, wells are frequently sunk into the rock to a moderate depth. In the driftless portions of Indiana and Ohio, also, wells of this class form a main source of supply. In the early days of settlement such wells were excavated or blasted and have a diameter of several feet, but since the drill has been introduced into this region large wells are rare. Usually a 4-inch or 6-inch drill is employed, and the well is sunk to a depth of several feet beyond the point where water enters, in order to obtain either a basin or a greater contributing surface. Where wells are sunk in sandstone such deepening usually results in a strengthening of the well, and in limestone there is but rarely a loss of water supply caused by sinking to a level below the water vein.

In this class of wells the head is seldom such as to cause an overflow, for the supply is usually from a moderate depth and is furnished by absorption of rain water in the immediate vicinity of the well. The depth of this class of wells ranges from 10 feet or less to 200 feet or more. The deeper wells, however, are not usually supplied by absorption from the immediate vicinity.

There is much difference in the strength of these wells in different rock formations. In some formations strong wells may usually be obtained, while in others the majority are weak. Probably the best horizon for this class of wells in the region under discussion is the Niagara limestone. This limestone is not only fissured extensively, but is also in places sufficiently porous to transmit water readily. Its extensive outcrops in eastern Indiana and western Ohio and also in northwestern Indiana insure for these districts an abundance of water at comparatively slight depths. The water is often sulphurous, owing to the presence of iron pyrites in the limestone, but is on the whole pleasant and of good sanitary quality. This limestone in some cases affords wells that overflow or have strong hydrostatic pressure. This is especially true of the wells on the slope of the dome which finds its culmination in southern Randolph County, Indiana. Wells 200 to 250 feet or less in depth often have sufficient head to overflow.

The limestones of Lower Silurian age, which are extensively exposed in southwestern Ohio and southeastern Indiana, usually afford water

at convenient depth in sufficient amount to supply households, but are seldom of sufficient strength to supply a large number of cattle or other stock. Stock raising is therefore, as a rule, not undertaken on an extensive scale unless a farm is situated near a living stream. The water from this horizon, though hard, is usually very palatable and rarely has a sulphurous character.

Probably the poorest source for water is the Devonian shales, but these form only a small part of the area of either Indiana or Ohio as a surface outcrop. Where not overlain by rock they are usually covered by a drift sheet which yields a fair amount of water.

The Knobstone or Waverly group is a source of strong wells and numerous springs, both in the Indiana and the Ohio outcrops, as are also the other sandstones of Eocarboniferous age. The quality of water is excellent, being perhaps unsurpassed in average quality by water from any other horizon. It is usually sufficiently soft to be used for laundry purposes without "breaking," and thus avoids the difficulty experienced in the use of nearly all waters from the glacial drift, as well as from limestone formations.

The Eocarboniferous limestones which outcrop extensively in southern and western Indiana all furnish a fair amount of hard water and rank with the Niagara limestone as a water yielding formation.

The Carboniferous sandstones and shales which outcrop extensively in southwestern Indiana and in eastern Ohio are very irregular in their water capacity. They vary also greatly in the quality of water, some water being salt or sulphurous, while other water is soft and pleasant. In some places "copperas water" is found that is highly objectionable. In these formations the shallow wells usually afford a better class of water than the deep wells, though instances are reported of wells 300 feet or more in depth in southwestern Indiana which furnish water of agreeable taste.

The statistics concerning water supplies for cities and villages, given on subsequent pages, serve to indicate the depth at which wells are usually obtained in each of the several formations, and make further details unnecessary. The rock water of Ohio will be discussed by Dr. Edward Orton in a separate paper for this Survey.

ROCK WELLS WITH STRONG HYDROSTATIC PRESSURE.

A few artesian wells were made in the early days of settlement, but the great majority of borings in Ohio and Indiana have been sunk since the discovery of natural gas in these States about 1886. These borings for oil and gas were made without reference to the determination of water resources, and but little attention was given the water. The value of the water is greater than is popularly supposed, for the strong pressure exerted by it in the territory surrounding the gas and oil fields causes the pressure exhibited by the gas wells, and makes them

much more valuable than would be the case if there were not this strong hydrostatic pressure.

The sinking of these wells for oil and gas has also brought to light the existence of large supplies of potable water in the formations which are penetrated before the rocks yielding gas and oil are reached. In many instances these wells have passed potable water in the Niagara and found salt water in the Trenton. By plugging such wells between the potable and the salt water the former has been turned to use as a source for city water supply or for manufacturing and other industries.

Statistics are not available concerning the head except in a few instances. As a rule the water obtained from the Niagara limestone in the vicinity of the gas and oil field of eastern Indiana and western Ohio has greater head than that in lower strata. There are instances in which it reaches an elevation of fully 900 feet, while the Trenton water seldom much exceeds 600 feet in the same localities. But in northwestern and western Indiana the difference in head between the waters from the Niagara and from lower formations is usually slight, not far from 600 feet. It appears to be somewhat higher in northwestern Indiana than in the western and southwestern portions of the State. In southern Indiana a few wells have been obtained which show a head not far from 600 feet, and the head in central Indiana is apparently about the same.

Several wells from the Niagara in western Indiana yield a sulphosaline water which has gained a wide reputation as a restorative to diseased and enfeebled persons. Several sanitariums have been constructed for the accommodation of persons who resort to these wells. Those at Martinsville, Spencer, Greenwood, Lafayette, and Montezuma have wide reputations. Analyses of the waters from these and other deep wells in western Indiana appear on subsequent pages.

Concerning the absorption areas from which deep wells are supplied some uncertainty exists. It is thought that wells from the Niagara limestone in the eastern part of Indiana and western Ohio have their absorbing area in the elevated area of Randolph County, Indiana, and adjacent counties. In northwestern Indiana the source is apparently from outcrops in northern Illinois or southeastern Wisconsin. Between these two districts there is a large area in which the direction of intake and transmission is uncertain. It is also uncertain in southwestern Indiana.

The horizons from which water is usually obtained in the artesian wells of Illinois and southern Wisconsin, namely, the Potsdam and St. Peter sandstones, and to a less amount in Lower Magnesian and Trenton limestones, are at so low a level in the States of Indiana and Ohio that they do not furnish a convenient source of supply, even if the water should be of suitable quality. The borings for natural gas, however, have shown that the water in all these formations is brackish or too saline to be of suitable quality for drinking. It is not likely, therefore, to be sought for any purpose, unless it be as a source for salt.

The Eocarboniferous limestone and sandstone, and also certain sandstones of the Carboniferous in southwestern Indiana, yield water having strong hydrostatic pressure and occasionally furnishing an overflowing well. Wells in these formations vary greatly in the quality of water; a few are fresh, but the majority are brackish, and some are highly saline, as may be seen by the analyses on another page. On the whole, these formations do not promise to yield waters of a quality to justify extensive development. Wells sunk to a depth of 100 to 200 feet seem more likely to obtain a potable water than those of greater depth.

Since the character of the rock water of Ohio is to be discussed by Professor Orton, for this Survey, further remarks concerning its character seem unnecessary in this place. A few detailed records of wells in Indiana, illustrative of the above statements, are given below.

WELLS IN INDIANA.

Anderson.—This city has one artesian well, 800 feet in depth, situated in White River Valley near the waterworks pumping station. This water is pumped to nine hydrants in the city. It is reported to be strongly impregnated with magnesia, iron, and sulphur. Probably the supply is largely from Niagara limestone.

Attica.—A strong overflow was obtained in a boring in the Wabash Valley at this city. The water is strongly sulphurous, but otherwise not unpleasant. The depth, head, and geological horizon are not known to the writer.

Bloomington.—A section of a boring 2,730 feet in depth is published in the Geology of Indiana,[1] and is interpreted by Dr. Phinney to enter the Lower Magnesian limestone about 50 feet. Water is reported at only two levels; first, in the St. Louis limestone, within 30 to 35 feet of the surface; second, in the Lower Magnesian limestone, at 2,722 to 2,730 feet. It was the original intention to continue the boring to a depth of 3,000 feet, but the machinery became fastened and the work was abandoned.

Brownstown.—The gas-well boring at this village shows an interesting difference in the head of the water in the Niagara limestone and that in the St. Peter sandstone, an overflow being obtained from the former at an altitude about 650 feet above tide, while from the latter the head is only about 350 feet. The upper water is a sulphurous-magnesian water, while the lower water is strongly saline.[2] The St. Peter sandstone was penetrated 47 feet, but the salt water was found only at the bottom of the well, and adequate passage for the water may not have been opened.

Columbia City.—The waterworks are supplied from three 8-inch wells in limestone about 280 feet in depth, which overflow to a height of about 5 feet above the surface and about 800 feet above tide. The supply is perhaps in part from the sand beds in the lower part of the drift. A gas-well boring at this city, 1,375 feet in depth, struck salt water at 900 feet, which rose to within 20 feet of the surface, but water struck in the Trenton at the bottom of the well rose only 300 feet, or to a level 1,075 feet below the surface and about 260 below tide.[3] The extremely low head in the Trenton water is perhaps due to a failure to open a passage for this water, for at the neighboring village of Larwill, where a well penetrated the Trenton 50 feet, the water rose to 750 feet above tide.

Columbus.—Dr. Phinney reports that salt water struck in the Trenton limestone at a depth of 1,005 to 1,020 feet overflows at an altitude 635 feet above tide. St.

[1] Fifteenth Report, 1885-86, p. 332.
[2] Phinney, Eleventh Ann. Rept. U. S. Geol. Survey, p. 726.
[3] Ibid., p. 736.

Peter sandstone was entered at about 1,550 feet and penetrated to a distance of 150 feet, but its head, compared with that of the Trenton, was not determined.

Converse.—Many wells in the vicinity of this village obtain water in the Niagara limestone at depths of 200 to 250 feet, which rises nearly to the surface. The waterworks supply is from wells 230 feet in depth, which rise within about 8 feet of the surface, or about 800 feet above tide. Brackish water is entered at about 435 feet. Care is therefore taken to stop drilling where the water is fresh.

Corydon. -A well 1,200 feet in depth, bored for salt brine in 1871 and 1873, struck saline sulphur water in St. Louis limestone at 48 to 57 feet. The brine became stronger farther down, having a strength of 30 degrees at 520 feet and 38 degrees at about 700 feet, where the maximum strength was reached. In Upper Silurian limestone at 879 to 900 feet and in Lower Silurian limestone at 986 feet sulphur water was found.[1] A white sulphur water is obtained in the St. Louis limestone at a well 1 mile east of the village, which has been used in a small natatorium.

Crawfordsville.—A gas-well boring at this city struck sulphur water at a depth of 750 feet. Water was also obtained in the Eocarboniferous limestone at 240 feet.

Crown Point.—Dr. Phinney reports that a gas-well boring at this village struck salt water in the Trenton at about 930 feet, which rose to within 120 feet of the surface, or to a level 616 feet above tide.

Delphi.—Salt water struck in the Trenton at about 910 feet rises nearly to the top of the well, 600 feet above tide. (Phinney.)

Edinburg.—Salt water struck in the St. Peter sandstone at a depth of 1,580 feet rises within 83 feet of the surface, or 585 feet above tide. An analysis of this water appears on a subsequent page. (Phinney.)

Elkhart.—At this city a flow of water is obtained from limestone immediately below the Devonian shale at a depth of about 550 feet. As noted above, fresh water is obtained in the drift, which also overflows.

Elwood.—The public water supply is from a series of wells drilled to depths of 75 to 150 feet, which rise to within 15 to 25 feet of the surface. Wells of much greater depth are likely to enter a brackish water.

Evansville.—Several deep wells have been sunk at Evansville, which obtain a brackish water. One of these wells, 1,100 feet in depth, has been used to supply a natatorium.

Fort Wayne.—A well 3,000 feet in depth was sunk at the court-house in 1875, which has a head 8 feet below the surface, or 785 feet above tide. The water appears to be from a horizon near the surface of the well, for its temperature is but 51¼° F. Dr. C. R. Dryer reports that a well in the Maumee Valley at this city overflows with considerable force.[2]

Goshen.—Salt water overflows at this city from the Niagara and possibly from the Trenton limestone. It is struck in the former at about 1,000 feet and in the latter at about 1,800 feet. The altitude of the well mouth is 785 feet, or higher than the Trenton water is known to reach at any other point. The Niagara water, as already indicated, reaches greater elevation than this at points to the East.[3]

Gosport.—A well 926 feet in depth was bored in the autumn of 1895 in the valley of White River adjacent to this village at an altitude 580 feet above tide. The well is cased about 500 feet to shut out salt water. It obtains a strong flow of "white sulphur" water, probably from Niagara limestone near the bottom of the boring. The water will flow freely at top of a pipe 30 feet above the mouth of the well, or 610 feet above tide. A strong vein of fresh water was struck at 125 to 150 feet, which rose within 20 feet of the top. (Data furnished by G. B. Spicer and L. D. Ray, Gosport, Indiana.)

Greenfield.—The city water supply is from overflowing wells obtained in the Niag-

[1] Geology of Indiana, 1872, pp. 146 to 147; 1878, pp. 353 to 355.
[2] Indiana Geology, Sixteenth Report, 1888, p. 127.
[3] See Eleventh Ann. Rept. U. S. Geol. Survey, p. 735.

ara limestone at a depth of 176 feet. The altitude of the well mouth is nearly 900 feet above tide. It is possible that a portion of the supply is from the sand beds in the drift, though it is generally supposed to be entirely from the rock. (Data furnished by S. S. Boots, M. D.)

Greenwood.—Two deep wells have been sunk at this village, one to a depth of 600 feet, the other to 1,975 feet. The former is cased only to the rock—210 feet—and water rises within 45 feet of the surface. It terminates in the Hudson River limestone, and probably receives much of its water from the Niagara, which is entered at about 320 feet. The deeper well has a head 240 feet below the surface. The water enters at a depth of 1.840 to 1,865 feet, and is apparently from the St. Peter sandstone. A sanitarium has been constructed into which water from both wells is pumped. The water from the deeper well is pumped into elevated tanks without intermixture with other water and thence conveyed to all parts of the sanitarium building. The water from the shallower well is much more fresh than that in the deeper one. (Data furnished by John A. Polk.)

Hammond.—Artesian well water from wells about 1,900 feet in depth were used some years ago for domestic purposes and also for distilleries and factories. The use of such water has been displaced by that of the public water supply from Lake Michigan, as it was found unsuitable for boilers. (Data furnished by W. F. Bridge, city engineer.)

Huntington.—A gas-well boring 1,030 feet in depth entered Trenton limestone at 1,002 feet, from which salt water rose within 87 feet of the surface, or to a level about 640 feet above tide.[1]

Indianapolis.—Wells drilled by the Indianapolis Water Company near the bank of White River strike water in the Niagara limestone which rises a few feet above the level of the river, or about 700 feet above tide. (Data furnished by F. A. W. Davis, superintendent.) Dr. Phinney reports several borings in the vicinity of Indianapolis which struck salt water in the Trenton at a depth of about 1,000 feet, from which there is a rise of 700 feet or more in the wells.[2]

Kentland.—A well bored for gas to a depth of 1,325 feet has an abundant supply of sulphur water, which stands within 45 feet of the surface, or 635 feet above tide. The water supply is probably in large part from the Niagara limestone, for wells in the neighborhood of the town obtain a similar water to that of the deep borings from the Niagara limestone at depths of 250 to 300 feet. The deep boring entered the Trenton limestone about 260 feet, but water from that horizon may not reach the surface. Several flowing wells are obtained from the drift in the vicinity of this village at depths of 40 to 120 feet. (Data furnished by W. T. Drake.)

Kewanna.—Dr. Phinney reports a rise of 990 feet in salt water struck in the Trenton at this village at a depth of 1,074 feet, the altitude of the well being about 790 feet. The head is about 700 feet above tide [3]

Kokomo.—The district immediately west from Kokomo yields water instead of gas. The water from the Trenton is salt, but that from the Niagara is comparatively fresh and has been turned to account by some of the farmers on whose land the wells were sunk, for many of the wells overflow or rise nearly to the surface. One instance of the use of a well for irrigation is reported, the well being on the farm of W. H. Wolf. It is probable that the fresh water of the Niagara fills the upper portion of all deep borings and the supply of potable water may be obtained without penetrating to the lower strata.

Lacrosse.—A gas-well boring drilled in sec. 23, T. 33, R. 4 W., about 3 miles from Lacrosse, obtained a supply of water which is said to be preferred by cattle and other animals to the water found in the shallow wells or the surface water of the Kankakee marsh. Water stands at about the level of the surface of the ground (675 feet above tide). Depth of well, 838 feet. (Data by R. Huncheon.)

[1] Phinney, Eleventh Ann Rept U S Geol. Survey, p. 739 [2] Ibid., pp. 700, 701. [3] Ibid., p. 733.

Lafayette.—"White sulphur" water was found at this city about forty years ago by boring to a depth of 235 feet in the valley of the Wabash River. The water is obtained near the top of the Niagara limestone. It flows about 10 barrels per hour and has a temperature of 55° to 56°. An analysis appears on a subsequent page. A gas-well boring a thousand feet in depth also obtains a strong flow of sulphur water. The head is not determined, but the altitude at the wells is nearly 550 feet above tide. (Data furnished by Prof. H. A. Huston.)

Larwill.—Dr. Phinney reports that at the gas-well boring made at this village the first vein of salt water was struck at 935 feet and rose 800 feet; a second vein was struck at 997 feet, which rose 850 feet, and salt water again appeared in the Trenton at 1,566 feet, which rose within 200 feet of the surface, or to an elevation of about 750 feet above tide.[1]

Leavenworth.—A weak flow of sulphureted chalybeate water was obtained in this village some thirty years ago at a depth of 235 feet. The well is located in the Ohio River valley, in the eastern part of the town, at an elevation about 400 feet above tide.[2]

Lodi.—A boring for oil at this village made in 1865 reached a depth of 1,155 feet, and struck several veins of brackish water. Near the bottom it struck a white sulphur water either in the Devonian or Upper Silurian limestone. A detailed section of this boring is given in the Geology of Indiana, 1869, and also in the report for 1881. An analysis of the water is also published in both reports and may be found on a later page in the present paper. The water has a wide reputation for medicinal properties and is shipped to distant points, as well as resorted to by people of the vicinity.

Logansport.—The gas-well borings of this city, about 1,100 feet in depth, struck a salt water in the Trenton limestone which overflows at an altitude of about 610 feet. (Phinney.)

Marion.—Fine artesian flows of fresh water are found at Marion and other localities in Grant County, in the Niagara limestone, at depths varying from 240 to 290 feet. A portion of the waterworks supply is obtained from wells 240 feet in depth, which overflow. It is estimated that a well 8 inches in diameter has a capacity of 150,000 gallons per day. (Information furnished by Dr. Phinney and by city mayor.)

Martinsville.—The natural-gas boring made at this city a few years ago brought a flow of sulphur water which has since gained such wide reputation for its medicinal properties that at the present time six sanitariums are necessary to accommodate the persons who are availing themselves of this water. Each sanitarium has a well sunk to a depth of nearly 700 feet, the shallowest being 668 feet and the deepest 704 feet. The gas boring referred to above reached a depth of 1,472 feet. Analyses of waters from several of these wells appear on a subsequent page. It will be observed that they present some differences in relative amounts of each of the mineral ingredients, but the waters are all sulpho-saline. The head has been determined at several of these wells and found to be 620 feet above tide. After penetrating the drift, which is 90 to 117 feet in thickness, the wells pass through a heavy shale formation over 400 feet in thickness. Limestone is then entered, which, at about 600 feet from the surface, becomes water bearing. The amount of water increases within the next 75 or 100 feet to its maximum flow. The rate of flow per minute has been determined at several of the sanitariums, as follows: Home Lawn Sanitarium, 40 gallons; Highland Sanitarium, 25 gallons; Barnard's Sanitarium, 28 gallons; Martinsville sanitarium, 35 gallons. The rate of flow at the other two sanitariums has not been determined. The size of the wells differs slightly, but is usually between 5 and 6 inches. The tests recorded above are made through pipes of smaller diameter forming an inside casing. There are two other borings in the vicinity of Martinsville, not accompanied by sanitariums, which reach a similar depth and have an overflow

[1] Eleventh Ann. Rept. U. S. Geol. Survey, p. 736.
[2] See Geology of Indiana, 1878, p. 436.

of sulpho-saline water. One is located on the grounds of the Forest Grove Park Association and the other on the farm of C. S. Cunningham, about 1½ miles southwest of the city.

Michigan City.—A boring was made several years ago at the Northern Indiana Penitentiary, about a mile west of Michigan City, which obtained a strong flow of water highly charged with sulphureted hydrogen. The rate of discharge is estimated to be about 300 gallons per minute. The head is 22 feet above the surface, or about 620 feet above tide. The water has a temperature of 57° F. The section of the well is as follows: Glacial drift, 172; Devonian shale, 76; Limestone, largely Niagara, 293 feet; total, 541 feet. A gas-well boring in the city and a boring on the Blair farm, 2 miles west, each obtain strong flows of sulphurous water from the Niagara limestone. In all three wells strong flows of water were also obtained in sand beds in the lower part of the glacial drift.

Mitchell.—A gas boring 1,200 feet in depth struck two veins of brackish water, from which water rises within 30 feet of the surface, or to a level about 645 feet above tide. This water is used for street sprinkling, there being no waterworks in the village. (Data furnished by J. T. Dilley.)

Monon.—A gas boring at this village struck salt water at 880 feet, near the top of the Trenton, which rose almost to the surface, 650 feet, more or less, above tide. At Monticello, only a few miles distant, salt water struck in the Trenton at 1,050 feet rose only 500 feet in the well. It is probable that the latter well failed to open an adequate passage for the water. Possibly, also, the Monon well owes the high head partly to an influx of water from the Niagara limestone.[1]

Montezuma.—A boring about 1,700 feet in depth struck a vein of salt water at 300 feet and another about 450 feet which have sufficient head to rise to the surface. At about 1,200 feet, immediately beneath the Devonian shales, a sulphur water was struck which rises with great force to a height of fully 100 feet above the surface, or about 610 feet above tide. It is reported that water was made to rise in a tube 115 feet above the surface, or 625 feet above tide. An analysis of the water is given on a subsequent page. A large swimming pool has been constructed, which is filled with this water. The rate of flow of the well is estimated to be about 475 gallons per minute. (Data furnished by Joseph Burns.)

Muncie.—The city water supply is obtained from artesian wells drilled in the valley of White River. The supply is from the Niagara limestone. (Data obtained from Manual of American Waterworks.)

New Haven.—The waterworks supply is from a well in the Niagara limestone, 300 feet in depth. The first vein of water was struck at 150 feet and raised within 1 foot of the surface. A second vein struck at about 300 feet has a head 11 feet above the surface, or nearly 750 feet above tide. An analysis of the water is given on a subsequent page. (Data furnished by D. H. F. Berberick.)

North Manchester.—A gas boring struck salt water at 1,180 feet which rose 990 feet in the well, reaching an elevation of about 600 feet above tide. Flowing wells are obtained from the drift in this vicinity at about 100 feet, as noted above. The waterworks supply is from such wells.

North Vernon.—A gas boring 1,400 feet in depth struck salt water in St. Peter sandstone at 1,400 feet which rose to about 200 feet from the surface or 500 feet above tide. (Phinney.) A flowing well of great strength was obtained near North Vernon, in Niagara limestone, at 66 feet.

Peru.—A gas-well boring struck salt water in the Trenton at about 900 feet, which rose 800 feet in the well, or to an elevation of about 550 feet above tide.[2]

Reelsville.—An artesian well was made many years ago at Reelsville, in the valley of Walnut Creek, at an elevation of about 600 feet above tide. The depth was 1,240 feet, and salt water was obtained at several horizons. The well terminated in the

[1] Phinney, Eleventh Ann. Rept. U. S. Geol. Survey, p. 731.
[2] Ibid., p. 733.

Niagara, where a white sulphur water was obtained.[1] At the time this well was struck the water rose in a copious stream to a height of fully 20 feet above the surface. No recent data concerning it have been obtained.

Rensselaer.—A well was made many years ago just east of the village, which obtained a strong flow of sulphureted water from a depth of 180 feet, but the boring was extended to a depth of 800 feet. Another well at the court-house struck water at similar depth, which rises nearly to the surface.[2] Numerous wells in the drift in that vicinity obtain a flow of water, and wells at all depths in the rock show a strong rise of water.

Seymour.—In a gas-well boring sulphur water was struck at 250 to 257 feet, and again at 345 to 385 feet in limestone, probably of Upper Silurian age. The head is sufficient to bring the water nearly to the surface, 630 feet above tide. The total depth of this boring is 1,204 feet. A boring owned by the Seymour Mineral Company was drilled in 1892 to a depth of 500 feet, obtaining water at the same horizon noted above in the gas well.

Shoals.—A boring 960 feet in depth made in the East White Valley, just east of the village, has a weak flow of salt water, which contains also a notable amount of lithium chloride and magnesium bromide, as shown by an analysis on a subsequent page. This water has been shipped to distant points, and is held in high esteem by the residents as an alterative and restorative.

South Bend.—A gas-well boring at this city reached a depth of 1,600 feet, and struck salt water at three horizons, as follows: At 375 feet, near the top of the Devonian limestone; at 610 feet, in limestone, thought to be the equivalent of the Lower Helderberg, and at 1,670 feet in the upper part of the Trenton. From the latter depth it is reported to rise within 200 feet of the surface, or to about 525 feet above tide. (Phinney.) As noted above, numerous flowing wells are obtained along the St. Joseph Valley in South Bend and vicinity.

Spencer.—Three wells at this city have been sunk to the Niagara limestone for the purpose of obtaining the sulpho-saline water which it yields. The depth of each of the wells is about 1,150 feet. A salt water is found in Subcarboniferous limestone at a depth of 450 feet, which is cased out in order to obtain the unmixed water from below. At one of these wells a large sanitarium has been built by Dr. E. V. Green, and an analysis of the water appears on a subsequent page. The capacity of the well at the level of the surface of the ground is about 200 gallons per minute, as it issues from a 4-inch casing. The head is sufficient to cause it to overflow from a pipe at a level 65 feet above the well mouth, or 625 feet above tide, and it apparently will rise much higher. A well made at the court-house supplies hydrants in the city, which are used extensively. The third well is on the Fletcher farm, about one-half mile northeast of the court-house.

Sullivan.—A gas well was sunk to a depth of 1,000 feet, and obtained a very strong brine, which rises within 15 feet of the surface, or about 525 feet above the tide. The water is used for street sprinkling, and makes a heavy coating of salt when evaporated. Another boring made by the Evansville and Terre Haute Railway Company in the valley of Busseron Creek, about 2 miles southeast of Sullivan, obtained an overflowing well of great strength, which is not put to use. Its depth is thought to be about the same as that of the well in Sullivan.

Summitville.—The gas-well boring at this village is reported by Dr. Phinney to have obtained a strong flow of water from the Niagara limestone at a depth of 140 feet. The altitude of the well being 896 feet, the flow was unexpected. Whether it is maintained has not been learned.[3]

Terre Haute.—A boring made by Mr. Chauncey Rose many years ago reached a depth of 1,793 feet, passing through three horizons of salt water in the Carbonifer-

[1] See Geology of Indiana, 1869, p. 31.
[2] See Geology of Indiana, 1872, p. 298.
[3] See Eleventh Annual Report U. S. Geol. Survey, p. 709.

ous rocks, and one or more in the Subcarboniferous. In the lower 100 feet of the well a strong flow of sulphur water was obtained. It is thought that the well terminated near the base of the Subcarboniferous limestone. An analysis of the water appears on a subsequent page. Afterwards several other wells were sunk in this city on account of a showing of oil found in the Rose well, one of which was continued through the Devonian into the Niagara and Clinton. As these wells were sunk for the purpose of obtaining oil, the water was cased out and few data appear to be available. Several detailed records of rock strata are published in the Twenty-first Annual Report of the Indiana Geological Survey, 1897.

Wabash.—A well at the court-house square on the bluff of Wabash River, 85 feet above the stream and more than 700 feet above tide, was sunk to a depth of 2,270 feet. The boring started in the Niagara limestone, and water was reached at 85 feet, the level of the river. No increase in head was obtained from the lower veins, though several were encountered. Temperature tests were made at 100, 500, 1,000, and 2,270 feet, which show the water to be uniform at 50½° F. at all these depths. The inference to be drawn from this uniform temperature is that the well is filled with water from an upper stratum and the temperature which it receives at that horizon is, by means of the greater specific gravity of cold water, carried down to the bottom of the well. This matter is discussed quite fully in the Geology of Indiana.[1]

West Fork.—At West Fork, Crawford County, Indiana, a few miles west of Leavenworth, a sulphur well of some note, known as "Eaton's sulphur well," was bored in the years 1862 and 1863. It is 4 inches in diameter and 284 feet in depth, and the flow is obtained from the lower part of the St. Louis limestone. The water from this well has a high reputation and has been sold extensively. A hotel is built for the accommodation of patrons of the well.[2] An analysis appears on a subsequent page.

Williamsport.—A gas-well boring 1,200 feet in depth struck a strong vein of fresh water at a depth of 65 feet and another at a depth of 165 feet. The second vein furnished an overflow. Salt water was struck at about 1,200 feet. After failing to obtain gas the salt water was plugged off and the fresh water was made available. (Data furnished by J. C. Russell.)

Winamac.—A gas-well boring 1,200 feet in depth obtained a flow of water which discharges at the rate of 45 gallons per minute. The depth of the water vein is not reported. It is said to be chalybeate.

Worthington.—A boring 1,445 feet in depth struck a strong flow of sulphur water at 1,430 feet, which appears to be similar to that struck at Spencer at about 1,100 feet, and probably from the Niagara limestone. The water has been piped to a hotel, where it may be used for drinking and bathing. (Data furnished by A. F. Wilson.)

MINERAL SPRINGS.

In a bulletin of this Survey prepared by Dr. A. C. Peale, a brief discussion of the mineral springs of Indiana and Ohio is included.[3] Thirty springs are noted from Indiana and twenty from Ohio which are or have been used either commercially or as a resort, and analyses of those most extensively used are presented. Many unimproved springs are also listed, and artesian wells used for medicinal purposes are included in Dr. Peale's tables.

Many of the springs have only a local reputation, but a few have become widely known. Perhaps those of widest reputation in Indiana

[1] Report for 1875, pp. 43–48.

[2] See Geology of Indiana, 1878, pp. 443–444.

[3] Mineral Springs of the United States, by Albert C. Peale, M. D.: Bull. U. S. Geol. Survey No. 32, 1886, pp. 130–141.

are French Lick and West Baden springs, Orange County; Degonia springs, Warrick County; Indian and Trinity springs, Martin County; West Saratoga springs, Pike County; Van Cleve springs, near Crawfordsville; and Hawkins springs, at Richmond.

In Ohio, among the springs of wide reputation should be mentioned Bellbrook magnetic spring, at Bellbrook, Greene County; Blue Rock spring, in East Cleveland; Cuyahoga lithia and bitter springs, near Cleveland; Odevene and Lenape springs, at Delaware; Ohio magnetic springs, at Magnetic Springs, Union County; the electro-magnetic springs, near Woodstock, in Champaign County; and Green spring, in Seneca County.

As the writer has not made a special canvass of this subject, there may be other springs to which his attention has not been directed which are as important as those just noted. Many springs have come into prominence through well-directed advertising by their proprietors, which are apparently superior in no way to dozens of others which are unknown to the public, but which may have a local reputation. In preparing a list of mineral sp ings there is room for indefinite extension. There is scarcely a township in the drift-covered portions of Indiana and Ohio which does not afford springs that are slightly chalybeate. It is probable that an analysis would show waters similar to the iron springs of health resorts. So, also, there are numerous sulphur and iron springs, as well as calcic springs, issuing from rock ledges in many of the valleys of Indiana and Ohio. A list such as that prepared by Dr. Peale can not be considered complete, but it probably includes the majority of springs which have been brought into prominent notice. A reference to the reports of the State geological surveys will serve to show how widely such springs are distributed.

The temperature of the water, as reported by Dr. Peale, ranges in the Indiana springs from 43° F. at Blue Lick spring, in Clark County, to 57° at Trinity and West Baden springs. A shallow thermal well near Shelbyville has a temperature of 76°. The majority of the springs have a temperature of 50° to 55° F. The reported temperature ot the springs in Ohio ranges from 47° in Lenape spring, at Delaware, to 60° at Blue Rock spring, in East Cleveland. The temperature is given, however, for only a small per cent of the springs, so that the range may be wider than indicated by the table.

Many of the springs listed by Dr. Peale have a flow of less than 1,000 gallons per hour, and the cold (Blue Lick) spring in Clark County, Indiana, just noted, has a flow of but 1½ gallons per hour. Trinity springs, in Martin County, Indiana, are estimated to furnish 18,000 gallons per hour. West Baden springs flow 1,500, and French Lick at least 1,100 gallons per hour.

The following springs used as resorts in Indiana are reported by Dr. Peale to have a saline-sulphureted water: French Lick, Orange County; Hartford sulphur springs, Crawford County; Blue Lick, Clark County;

Indian and Trinity springs, Martin County; New Middletown springs, Harrison County; and West Baden springs, Orange County. In Ohio, Blue Rock spring, at East Cleveland, is of this character. The magnetic springs at Bellbrook and Delaware and at Magnetic Springs are all reported by Dr. Peale to be calcic, no mention being made of chalybeate character. Two analyses from the Lenape springs show about one-half grain of iron oxide per gallon, and one from the Bellbrook gives less than one-fourth grain, while the Ohio Magnetic, at Magnetic Springs, and the Electro-Magnetic, near Woodstock, show only a trace of iron oxide. Hawkins chalybeate springs, at Richmond, Indiana, appear to be misnamed, as only 0.18 grain of ferrous carbonate is reported in the analysis.

WATER ANALYSES.

In Ohio the State board of health is required by law to approve all public water supplies when introduced, and it has in accordance with this law in every case made an analysis of the proposed supply. The analyses may be found in their annual reports. In Indiana also steps are being taken by the State board of health for a similar publication of analyses.

In many cases waters have been analyzed independently of the boards of health. Several such analyses have been sent to the writer in connection with the schedules for city water supply, and are here presented. A few analyses of the artesian wells, mineral springs, and other waters of special interest also appear. Sanitary analyses are presented in the discussion of city water supplies.

It will be observed that the deep wells usually contain a much larger amount of mineral matter than the springs and shallow wells. The French Lick, Indian, and West Baden springs of southern Indiana are, however, heavily charged with mineral matter, as are also the springs near Cleveland and Green spring in Seneca County, Ohio. The majority of springs and shallow wells are slightly saline, while the deep wells are usually strongly saline. The tables following illustrate what has already been stated to be a general condition in Indiana and Ohio. They also set forth fairly, as it seems, the variations in quality of water found in this region, and afford a basis for instructive comparisons.

In a few of the waters included in this table of analyses substances have been found which are not reported in the table. They may be found in a large proportion of the waters, since analyses are seldom complete.

Alumina is found in measurable quantities in the following: Marion, Indiana, 0.29 grain; Greencastle, Indiana, "No. 1," 0.15 grain; "No. 2," 0.07 grain; Shoals, Indiana, 0.62 grain; Spencer, Indiana, 0.697 grain; Cuyahoga lithia springs, near Cleveland, Ohio, 17.67 grains; Dayton, Ohio, "No. 1," 0.3599 grain; "No. 2," 0.3251 grain; Defiance, Ohio, 0.36 grain; Green spring, 0.98 grain; Ohio Magnetic spring, 0.12 grain;

New Paris, Ohio, 0.22 grain; Ripley, Ohio, 0.68 grain; Van Wert, Ohio, 0.09 grain.

Aluminium sulphate is reported as follows: West Baden "No. 1," 4.55 grains; Bellefontaine, Ohio, 2.92 grains; Cuyahoga bitter spring, 515.51 grains. In this connection attention is called to the occurrence of "bitter water" in wells in the drift in the vicinity of Bellefontaine and thence eastward past Marysville to the vicinity of Delaware, Ohio. Numerous instances are reported in the Geology of Ohio, and such water is in some localities so prevalent as to give them the name of "bitter water districts." So far as known to the writer no analyses of these waters have been made. They may contain aluminium sulphate, but their bitter taste appears to be due to some other ingredient.

Aluminium chloride is reported in but one analysis, the Cuyahoga lithia water, which contains 17.67 grains.

Calcium phosphate is reported as follows: Lafayette, Indiana, 0.50 grain; Lodi, Indiana, 1.20 grain; Montezuma, Indiana, trace; New Paris, Ohio, 2.13 grains.

Calcium sulphide appears in the following: Montezuma, Indiana, 3.55 grains; Shoals, Indiana, 24.43 grains; Spencer, Indiana, 0.392 grain; Ripley, Ohio, 14.90 grains. At Shoals, Indiana, 18.88 grains of calcium disulphide and 33.072 of calcium hyposulphide are reported. The water at Ripley, Ohio, also contains calcium hyposulphide, 2.58 grains.

Iron is usually reported in the form of oxide, but in the following cases ferrous carbonate is reported: Anderson, Indiana, springs, 0.98 grain; Crawfordsville, Indiana, 0.62 grain; French Lick spring, 2.49 grains; Greencastle spring, "No. 1," 0.40 grain; "No. 2," 2.37 grains; Mifflin, Indiana, well, 8.925 grains; Richmond, Indiana, springs, 0.18 grain; West Baden spring, "No. 2," 3.60 grains (including aluminium carbonate); Eaton's well at West Fork, Indiana, 2.38 grains; Cuyahoga lithia spring, 0.82 grain; Cuyahoga bitter spring, 0.47 grain; Green spring, Seneca County, Ohio, 19.70 grains; New Paris, Ohio, 1.32 grains; Stryker, Ohio, 9.93 grains; Woodstock, Ohio, 16 grains. In the following cases ferrous sulphate is reported: Indian springs, 24.28 grains; Marion, Indiana, well, 1.48 grains; Green spring, Seneca County, Ohio, 6.53 grains. At Shoals, Indiana, and Ripley, Ohio, the iron is reported as sulphide, and at the Ludlow Grove salt well as chloride.

Lithium chloride is found in several of the wells and springs, as follows: Montezuma, Indiana, trace; Shoals, Indiana, 5.93 grains; Cleveland Blue Rock spring, 2.16 grains; Cuyahoga lithia spring, 2.74 grains; Cuyahoga bitter spring, 4.26 grains; lithium carbonate (8.84 grains) is reported in the Ripley analysis.

Magnesium bromide appears in the following analyses: Lodi, Indiana, 0.88 grain; Shoals, Indiana, 2.32 grains; Cincinnati sulpho-saline well, 0.39 grain; Ripley, Ohio, 0.52 grain. Potassium bromide (16.76 grains) is reported in the Green spring analysis, and sodium bromide (28.21 grains) in the salt well at Ludlow Grove, Ohio. In this connection it

may be remarked that the brines of Ohio are generally found to be rich in bromine.

Magnesium iodide is reported in three analyses, as follows: Shoals, Indiana, 0.004; Cincinnati artesian, 0.19 grain; Cincinnati sulpho-saline, 0.30 grain. Sodium iodide appears in small amount in two analyses, there being a trace at Montezuma, Indiana, and 0.20 grain in the Cleveland Blue Rock spring.

Magnesium sulphide is reported only in the Ripley analysis, 19.26 grains. Potassium sulphide is reported only at Spencer, 1.9 grains. Potassium nitrate is reported only at Shoals, 7.86 grains.

Sodium phosphate appears in two analyses: Cincinnati sulpho-saline well, 1.34 grains; Cleveland Blue Rock springs, 5.25 grains. Sodium silicate is reported only at Columbia City, Indiana (0.14 grain), and sodium sulphide at Spencer, Indiana (0.94 grain).

Ammonium chloride is reported in considerable amount, 8.35 grains, in the Shoals, Indiana, analysis.

Analyses of the waters of Indiana and Ohio. (*Grains per United States gallon.*)

INDIANA WATERS.

Locality.	Total solids.	Calcium carbonate and bicarbonate.	Calcium chloride.	Calcium sulphate.	Iron.	Magnesium carbonate and bicarbonate.	Magnesium chloride.	Magnesium sulphate.	Potassium carbonate.	Potassium chloride.	Potassium sulphate.	Silica.	Sodium carbonate and bicarbonate.	Sodium chloride.	Sodium sulphate.	Analyst.
Anderson (springs)	20.00	9.08	.....	5.56	0.98	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	E. T. Cox.
Andrews (well)	45.10	18.66	.....	1.59	.....	1.20	9.77	.....	.....	.....	.....	.....	.....	14.37	.....	W. E. Stone.
Brookville (waterworks)	(?)	12.37	.....	0.008	.....	6.41	.....	.....	.....	.....	0.035	0.032	.....	0.043	0.02	H. A. Huston.
Columbia City (waterworks)	(?)	18.96	.....	.....	0.107	0.52	.....	.....	.....	0 02	.....	.....	0.07	0.19	0.096	T. C. Van Nuys and I. T Metz.
Crawfordsville (spring)	22.84	9.80	.....	.....	0.62	3.82	.....	7.32	0.14	.....	.....	0.07	0.17	0 70	0.20	T. M. Stevens
Edinburg (gas well)	993.32	5.06	65.48	2.10	0.997	.....	.....	32.93	.....	.....	.....	1.99	10.43	874.32	.....	J. N. Hurty.
Elwood (waterworks)	22.85	11.08	.....	1.70	.....	6.41	.....	.....	.....	.....	.....	.....	.....	0.99	.....	(?)
French Lick (spring)	350.52	20 20	.....	141.00	2.49	4.50	8.05	29.33	.....	5.01	.....	1.69	10.52	90.92	36.72	J. G. Rogers.
Greencastle:																
Spring No. 1	22.10	14.50	.....	.....	0.40	4.72	.....	1.05	0.09	.....	.....	0.09	0.10	0.79	0.13	E. T. Cox.
Spring No. 2	21.80	11.90	.....	.....	2.37	5.34	.....	1.03	0.07	.....	.....	Trace.	0.06	0.70	0.01	Do.
Greensburg (waterworks)	21.55	12.48	.....	.....	0.30	6.44	.....	.....	.....	.....	0.23	0.71	0.51	0.59	.....	E. G. Smith.
Indian springs	196.45	39.73	.....	.....	24.29	22.74	0.07	36.48	2.89	.....	2.88	0.54	4 38	47.26	14.20	E. T. Cox.
Lafayette (artesian)	419.54	12.02	3.72	56.01	.....	0.40	21.66	.....	.....	.....	.....	0.46	.....	324.77	.....	C. M. Wetherell.
Lodi (artesian	672.45	2.01	47.93	55.56	.....	0.66	53.54	3.26	.....	.....	0.80	0.52	.....	502.46	2.13	J. C. Pohle.
Marion (flowing well)	23.20	14.00	.....	.....	1.48	2.34	.....	3.38	0.03	.....	.....	1.34	.....	0.32	.....	(?)
Martinsville:																
Barnard's Sanitarium	(?)	7.33	10.13	.....	.....	.....	7.51	.....	.....	20.45	0.89	Trace.	.....	18.71	1.09	(?)
Home Lawn Sanitarium	(?)	6.55	.....	.....	.....	5.35	.....	.....	.....	14.77	.....	8.45	3.27	55.86	1.69	W. E. Stone.
Martinsville Sanitarium	(?)	16.90	.....	.....	.....	15.35	.....	.....	.....	1.77	.....	0.55	2.48	58.58	1.87	Do.
Mifflin (well)	6,003.33	663.20	.....	29.07	8.92	179.38	.....	87.12	.....	.....	23 38	.....	5,021.40	.....	21.53	G. M. Levette.
Montezuma (artesian)	426.28	11.18	11.65	7.11	.....	17.88	9.97	.....	.....	2.68	.....	0.82	.....	357.71	.....	W. A. Noyes.
New Haven (waterworks)	(?)	7.18	.....	12.23	.....	0.06	.....	8.52	.....	.....	.....	7.58	.....	14.80	.....	(?)

Analyses of the waters of Indiana and Ohio. (*Grains per United States gallon.*)—Continued.

INDIANA WATERS—Continued.

Locality.	Total solids.	Calcium carbonate and bicarbonate.	Calcium chloride.	Calcium sulphate.	Iron.	Magnesium carbonate and bicarbonate.	Magnesium chloride.	Magnesium sulphate.	Potassium carbonate.	Potassium chloride.	Potassium sulphate.	Silica.	Sodium carbonate and bicarbonate.	Sodium chloride.	Sodium sulphate.	Analyst.
Newcastle:																
Waterworks No. 1	22.51	12.75	.....	.....	.....	6.12	.....	.....	.....	.....	.....	0.40	1.87	0.98	0.12	(?)
Waterworks No. 2	22.13	10.15	.....	.....	.....	7.82	.....	.....	.....	.....	.....	0.46	.....	1.78	1.90	(?)
Richmond (springs)	26.85	9.45	0.32	11.69	0.18	.....	.....	1.60	1.16	.....	.....	0.16	.....	0.33	.....	E. T. Cox.
Shoals (artesian)	1,518.54	32.52	20.20	2.65	1.37	.....	9.68	.....	.....	47.30	.....	2.72	.....	1,303.48	.....	Karl Laugenbeck.
Spencer (artesian)	121.67	12.22	8.11	.....	0.553	2.38	5.03	.....	.....	18.12	.....	0.32	4.17	66.84	.....	J. N. Hurty.
Tell City (artesian)	.....	.....	252.61	102.90	.....	.....	.....	.....	.....	.....	.....	1.28	.....	3,006.08	.....	Do.
Terre Haute (artesian)	365.07	25.03	4.82	2.32	.....	6.42	6.43	.....	.....	1.23	.....	1.20	0.52	316.00	.....	J. G. Pohle.
Trinity springs	26.73	5.61	0.70	1.27	.....	4.11	1.10	4.18	0.07	.....	0.10	0.82	0.12	8.34	0.35	
West Baden:																
Spring No. 1	235.25	41.28	7.26	11.18	0.08	39.10	11.39	36.15	0.06	.....	1.36	0.44	1.11	79.60	3.10	E. T. Cox.
Spring No. 2	301.80	19.44	6.13	108.34	3.60	6.05	9.20	27.77	.....	.....	.....	.....	9.70	80.21	31.70	Do.
West Fork (Eaton's well)	263.50	47.51	.....	11.46	1.98	16.80	.....	43.80	.....	.....	5.40	.....	.....	125.40	10.95	G. M. Levette.

OHIO WATERS.

Ashland (waterworks)	(?)	12.32	.....	.....	.....	3.00	.....	2.83	.....	.....	.....	1.28	1.56	1.00	.....	S. W. McKeown.
Bellbrook (spring)	26.79	15.52	.....	1.20	0.25	7.20	.....	.....	.....	.....	1.07	0.67	.....	0.85	0.03	N. W. Lord.
Bellefontaine (waterworks)	20.48	8.33	.....	3.62	.....	5.19	.....	.....	.....	.....	.....	.....	.....	0.42	.....	C. C. Howard.
Cincinnati:																
Artesian, 1,245 feet	617.32	17.33	22.26	27.27	0.37	8.14	18.14	.....	.....	3.27	.....	0.49	.....	519.60	.....	E. S. Wayne.
Well, 240 feet	642.16	19.34	22.19	29.20	0.43	9.13	17.27	.....	.....	3.95	2.30	0.79	.....	534.77	.....	Do.
Cleveland (blue-rock spring)	303.27	3.75	.....	.....	.....	56.81	.....	.....	6.75	16.10	.....	1.00	1.00	210.25	.....	J. L. Cassells.

Analyses of the waters of Indiana and Ohio. (*Grains per United States gallon.*)—Continued.

OHIO WATERS—Continued.

Locality.	Total solids.	Calcium carbonate and bicarbonate.	Calcium chloride.	Calcium sulphate.	Iron.	Magnesium carbonate and bicarbonate.	Magnesium chloride.	Magnesium sulphate.	Potassium carbonate.	Potassium chloride.	Potassium sulphate.	Silica.	Sodium carbonate and bicarbonate.	Sodium chloride	Sodium sulphate.	Analyst.
Cuyahoga:																
Lithia spring	515.82	11.08	.....	120.39	0.82	.....	.....	116.54	.....	.....	4.38	15.87	.....	222.19	4.14	(?)
Bitter spring	791.58	8.75	.....	50.16	0.47	.....	.....	172.07	.....	.....	1.57	19.31	.....	8 05	11.43	(?)
Dayton:																
Waterworks in 1887	16.87	7.94	.....	0.53	.....	5.22	.....	.....	.....	.....	0.52	0.18	.....	0.26	1.79	H. S. Jewett.
Waterworks in 1895	21.98	11.76	.....	0.006	.....	6.12	.....	.....	.....	.....	0.44	0.38	.....	0.42	2.52	Do.
Delaware:																
Lenape spring	55.70	27.42	0.63	6.20	0.54	15.21	.....	0.93	.....	.....	1.34	0.05	.....	3.35	.....	E. S. Wayne.
Lenape spring, No. 2	40.64	17.73	.....	5.12	0.41	12.11	.....	2.31	.....	.....	.....	.....	.....	2.15	.....	Do.
Odeveuel spring	375.11	33.87	15.26	102.47	0.05	2.64	55.93	.....	.....	18.65	.....	0.37	.....	145.87	.....	A. A. Breneman.
Defiance Sanitarium (artesian)	88.26	26.36	.....	4.58	0.80	7.62	.....	3.95	.....	Trace	.....	1.29	.....	20.85	2.35	J. N. Hurty.
Eaton (waterworks)	(?)	8.39	.....	2.18	0.017	4.95	.....	.....	.....	.....	.....	0.29	5.19	1.16	.....	(?)
Green spring, Seneca County	216.49	22.39	.....	105.41	19.70 6.53	.....	.....	36.14	.....	2.48	.....	6.10	.....	.....	.....	O. N. Stoddard.
Ludlow Grove (salt well 271)	5,738.10	6.33	786.61	6.07	53.46	14.06	542.04	.....	.....	.....	.....	1.22	.....	4,300.10	.....	E. S. Wayne.
Magnetic springs	44.90	19.20	3.27	.....	0.16	17.61	.....	2 30	.....	.....	0.22	0.24	.....	0.79	0.42	Do.
Marion (waterworks)	(?)	13.53	.....	1 24	Trace.	5.97	.....	.....	.....	.....	.....	1.40	.....	.....	7.82	(?)
Massillon (waterworks)	21.38	12.65	.....	0 79	0.06	5.47	.....	.....	.....	.....	0.13	0.59	.....	0.76	1.16	E. G. Smith.
New Paris (Cedar spring)	18.11	3.96	.....	1.24	1 32	5.82	.....	.....	.....	.....	.....	.....	2.26	0.98	0 18	A. Fennel.
Oberlin (waterworks)	35.35	1.16	.....	14.75	0 29	11.94	.....	.....	.....	.....	0.39	0.35	.....	2 96	3.44	F. F. Jewett.
Ripley (artesian)	(?)	.....	.....	1.46	0.041	.....	.....	.....	.....	23.18	.....	1 62	.....	530.76	.....	Karl Langenbeck.
Springfield (waterworks)	21.30	1.26 12.13	.....	0.09	.....	5.12	.....	.....	0.53	.....	.....	0.10	0 91	0.21	.....	(?)
Stryker (well)	621 51	68.30	.....	.....	9.93	.....	118.96	.....	.....	.....	185.34	2 63	.....	231 86	.....	S H. Douglass.

Analyses of the waters of Indiana and Ohio. (*Grains per United States gallon.*)—Continued.

OHIO WATERS—Continued.

Locality.	Total solids.	Calcium carbonate and bicarbonate.	Calcium chloride.	Calcium sulphate.	Iron.	Magnesium carbonate and bicarbonate.	Magnesium chloride.	Magnesium sulphate.	Potassium carbonate.	Potassium chloride.	Potassium sulphate.	Silica.	Sodium carbonate and bicarbonate.	Sodium chloride.	Sodium sulphate.	Analyst.
Van Wert (waterworks)	78.49	13.51	.....	27.37	0.12	.....	.....	26.14	.....	.....	0.69	0.89	.....	2.02	7.66	E. G. Smith.
Woodstock (springs)	61.33	26.24	4.22	.....	0.16	11.41	2.12	.....	.....	.....	2.91	0.24	.....	13.64	.....	E. S. Wayne.
Wyoming (waterworks)	19.72	10.06	.....	0.56	0.87	6.67	.....	.....	.....	.....	.....	6.87	.....	0.64	.....	(f)
Yellowsprings (spring)	23.17	19.57	1.54	1.35	0.39	.....	0.17	.....	.....	.....	.....	.....	.....	0.15	.....	Wayne and Locke.
Zanesville:																
Well	68.90	9.11	.....	42.01	.....	5.99	.....	.....	.....	.....	.....	.....	.....	2.78	.....	J. D. Lisle.
Waterworks	33.55	.....	.....	7.58	Trace.	.....	.....	3.74	.....	.....	.....	.....	.....	0.73	.....	Do.

WATER SUPPLIES FOR CITIES AND VILLAGES.

There is considerable variation in the water resources for the supply of cities and villages, some cities being entirely dependent upon wells, while others have easy access to streams, springs, and lakes. Several cities on the border of Lake Erie obtain their supplies largely by pumping from the lake. Lake Michigan is drawn upon to a slight extent by towns in Indiana situated on its borders. The cities along the main streams may generally use the stream water with safety. In addition to this they have usually an available supply of good water from wells of slight depth. Cities not located near the lakes or large streams resort, in some cases, to storage reservoirs formed by damming small streams, but the greater number depend entirely upon wells. In a few instances small lakes furnish the chief water supply. In rural districts and in villages which have no waterworks the supply is mainly from wells of moderate depth. Deep wells are less extensively used than in Illinois, owing to the salinity of the water in much of this region.

A study of the development of the water supply in cities shows that in the early days almost without exception they used shallow wells. But with the growth of the city these often either became inadequate or were found to be contaminated. A change was then made to streams if they were available.

The statistics concerning the cost of waterworks and systems used, contained in the tables which follow, in most instances have been furnished by the officers in charge of the waterworks or by citizens competent to furnish them. In the case of a few cities no response was obtained to the application for data, but in nearly all such cases the statistics necessary for completing the tables have been found in the Manual of American Waterworks,[1] published by the Engineering News.

In many cities where waterworks are constructed a large part of the citizens use private wells, in some cases because they consider the city water unpleasant, but more often to avoid the water tax. In the great majority of the towns on the uplands a good quality of water may be obtained at slight depth in beds of sand or gravel below till or other clay, or at reasonable depth in the underlying rock, where drift is thin or is absent. The cities and villages most liable to have polluted water from shallow wells are situated either in valleys or in the sand-covered districts which occur in the northwest part of Indiana, or on gravel districts on the border of moraines. In these situations there is liable to be too little clay to prevent the infiltration from cesspools. Several cities in valleys have regulations against the use of private wells that are subject to contamination, but there is need for more stringent regulations.

[1] The letter "M" appended to name of city or village indicates indebtedness to this Manual.

SURFACE WATER.

The use of surface water in Indiana and Ohio as a source of city water supply is shown in the following list, nearly complete, of the cities and villages in which this is the chief source of supply. The table of population indicates that surface water is used to some extent by about 400,000 people, or nearly one-fifth of the population of Indiana, but it is probable that not more than half the population in the cities which use surface water in that State obtain their supply from the waterworks, for private wells are extensively used in nearly all the cities and villages. Probably less than one-tenth of the population are dependent upon this source of supply.

In Ohio the cities using surface water have an aggregate population of about 1,130,000. In this State a much larger proportion of the population depends upon the waterworks system than in Indiana, for such cities as Cincinnati and Cleveland and several smaller cities, situated in valleys, supply nearly their entire population through waterworks systems. It is probable that at least one-fourth the population of Ohio, or nearly 1,000,000 people, are dependent upon surface water supplied to them through waterworks.

The sanitary analyses, some of which are given later in this paper, indicate that this source of supply is usually but little contaminated. Where proper precautions have been taken to locate the pumping stations out of reach of contamination by the city's sewage this source of supply is found to be less dangerous than that of a large proportion of the private wells. The city of Cleveland, which receives its water supply through a tunnel extended out beyond the reach of contamination by the city's wastage, is not often forced to use contaminated water. It is more fortunate in this respect than the city of Chicago, where seldom a year passes in which polluted water is not driven out to the intakes and pumped back for city use. Some dissatisfaction is felt because of the sediment carried by streams in their flood stages, but this is not generally a source of danger, and may to some extent be lessened by an improvement in the filter galleries. Several cities along the Ohio River have already introduced a system of infiltration wells which enables them to furnish water nearly free from sediment.

Cities in Indiana using surface water for waterworks.

Name. *a*	Population in 1890.	Supply.	Waterworks.		
			System.	Cost (to 1895). *b*	When put in.
Anderson (part)	10,741	White River (filtered)	Direct pumping	$150,000 Ex. 5,000	1886
Attica (M.)	2,320	Springs	Pumped to reservoir	50,000 Ex. 1,500	1874
Bedford	3,351	White River	Pumped to standpipe	65,000	1893
Bloomington	4,018	Springs	Direct pumping	80,000	1893
Borden (M.)	(?)	Impounded water	Pumped to reservoir	3,600	1894
Boonville	1,881	do	Pumped to standpipe	31,000	1896
Brookville	2,028	Infiltration well from Whitewater River	Pumped to reservoir	24,000 Ex. 1,275	1895
Cannelton	1,991	Ohio River	do	(?)	1892
Columbus (M.)	6,719	East White River	Direct pumping	32,000	1871
Connersville	4,548	Whitewater River	do	100,000 Ex. 1,800	1869
Covington (part)	1,891	Springs	Pumped to standpipe	50,000	1892
Crawfordsville (M.)	6,089	Springs and wells	Pumped to reservoir	425,000	1886
Delphi	1,923	Springs and creek	Pumped to tank and direct	45,000 Ex. 1,100	1892
East Chicago (M.)	1,255	Lake Michigan	Pumped to standpipe	98,000	
Evansville	50,756	Ohio River	Direct pumping	Ex. 30,000	1870
Fairmount	1,462	Back Creek (?)	(?)	25,000 Ex. 1,000	1894
Greencastle (M.)	4,390	Walnut Creek and wells	Pumped to standpipe	303,000	1886
Hammond	5,428	Lake Michigan	do	150,000	1888
Huntingburg	3,167	Impounded water	Standpipe and direct pressure	(?)	1893
Huntington (part)	7,328	Wabash River	Direct pumping	100,000	1891
Indianapolis (24 per cent)	105,436	White River	do	2,500,000	1870

a In the tables concerning water supply, towns with the letter "M" appended did not send in returns, and the Manual of Waterworks is our authority.
b "Ex." in this column means running expenses per annum.

Cities in Indiana using surface water for waterworks—Continued.

Name.	Population in 1890.	Supply.	Waterworks.		
			System.	Cost (to 1895). a	When put in.
Jasper	1,281	Patoka River	Pumped to reservoir	$10,000	1895
Jeffersonville	10,666	Infiltration from Ohio River	Pumped to standpipe	200,000 Ex. 4,500	1888
Lafayette	17,485	Infiltration from Wabash River	Pumped to reservoir	250,000 Ex. 10,000	1876
Laporte (M.)	7,126	Clear Lake	Direct pumping	150,000 Ex. 6,000	1870
Leavenworth (M.)	792	Spring	Pumped to reservoir		1896
Logansport	13,328	Eel River	Direct pumping	225,000 Ex. 5,000	1876
Madison	8,936	Infiltration from Ohio River and springs	Pumped to reservoir	(?)	1849
Michigan City	10,776	Trail Creek and driven wells	Direct pumping	Ex. 6,500	1888
Mishawaka (part)	3,371	St. Joseph River	do	60,000	1891
Mount Vernon (M.)	4,705	Ohio River	Pumped to standpipe	(?)	1860
New Albany	21,059	do	Pumped to reservoir	300,000 Ex. 25,000	1875
North Vernon	2,012	Muscatatuck	Pumped to standpipe	28,000	1892
Peru	7,028	Wabash River	Pumped to reservoir	170,000	1879
Princeton	3,076	Patoka River	Pumped to standpipe	70,000	1893
Paoli (M.)	707	Stream	Pumped to reservoir	5,500	1893
Richmond	16,608	Springs	Pumped to reservoir from filter galleries	250,000 Ex. 10,000	1886
Rockport	2,314	Ohio River	Pumped to standpipe or direct	25,000 Ex. 1,000	1886
Salem	1,975	Spring from a cave	Pumped to reservoir	20,000 Ex. 700	1886
Seymour	5,337	East White River	Pumped to standpipe	80,000 Ex. 3,600	1889

a "Ex." in this column means running expenses per annum.

Cities in Indiana using surface water for waterworks—Continued.

Name.	Population in 1890.	Supply.	Waterworks.		
			System.	Cost (to 1895). *a*	When put in.
Sullivan (M.)	2,222	Busseron Creek	Pumped to standpipe from impounding reservoir; filtered.	$40,000	1896
Tell City	2,094	Ohio River	Pumped to fire cisterns	(?)	(?)
Terre Haute	30,217	Wabash River	Direct pumping	600,000 Ex. 23,000	1873
Valparaiso	5,090	Flint Lake	do	100,000 Ex. 6,500	1886
Vernon (M.)	613	Muscatatuck River	Pumped to standpipe	4,300	1895
Vevay	1,663	Infiltration from Ohio River	Pumped to reservoir	18,000	1895
Vincennes	8,853	Wabash River	Pumped to standpipe or direct	370,000	1885
Whiting	1,408	Lake Michigan	Pumped direct	(?)	1890
Washington	6,064	White River	Pumped to standpipe	130,000 Ex. 2,000	1888
Warsaw (part)		Small lake	Pumped to standpipe and direct		1886

a "Ex." in this column means running expenses per annum.

Cities in Ohio using surface water for waterworks.

Name.	Population in 1890.	Supply.	Waterworks.		
			System.	Cost (to 1895). *a*	When put in.
Akron (part)	27,601	Small lake	Pumped to reservoir	$200,000	1880
Alliance	7,607	Mahoning River	Pumped to standpipe from settling basins	190,000	1883
Athens	2,620	Infiltration wells from Hocking River	Pumped to standpipe and direct	40,000	1894
Ashtabula	8,338	Infiltration wells from Lake Erie	Pumped to standpipe	300,000	1887
Bellevue	3,052	Impounded water	do	60,000	1873
Bridgeport	3,369	Ohio River	Martins Ferry works	(?)	(?)
Bellaire	9,934	do	Pumped to reservoir	175,000	1872
Bucyrus (part)	5,974	Sandusky River	Direct pumping	60,000 Ex. 5,180	1884
Conneaut	3,241	Infiltration wells from Lake Erie	Pumped to standpipe	125,000	1890
Canton (part)	26,189	Nimishillen Creek	Direct pumping	450,000 Ex. 24,000	1869
Cambridge	4,361	Wills Creek	Pumped to standpipe (under construction)	60,000	1896
Chillicothe (M)	11,288	Infiltration well, Scioto River	Pumped to reservoir	300,000	1881
Cleveland	261,353	Lake Erie	Pumped to reservoirs	7,088,486	1854
Columbus (main part)	88,150	Scioto River	Direct pumping	3,000,000 Ex. 100,000	1870
Cincinnati	296,908	Ohio River	Pumped to reservoir	8,000,000 Ex. 400,000	1820
Circleville	6,556	Infiltration wells from Darby Creek	Pumped to standpipe and direct	150,000 Ex. 4,000	1887
Crestline (M)	2,911	Springs with collecting basin	Gravity	120,000	1869
Dennison	2,975	Stillwater Creek	Pumped to reservoir	290,000	1888
Defiance	7,694	Maumee and Auglaise rivers and canal	Pumped to standpipe	200,000 Ex. 6,000	1888
Elyria	5,611	Black River	Pumped to standpipe and direct	125,000 Ex. 5,000	1879

a "Ex." in this column means running expenses per annum.

Cities in Ohio using surface water for waterworks—Continued.

Name.	Population in 1890.	Supply.	Waterworks.		
			System.	Cost (to 1895). *a*	When put in.
East Liverpool	10,956	Ohio River	Pumped to reservoirs, high service and low service.	$200,000 Ex. 12,000	1879
Fremont (main part)	7,141	Sandusky River	Pumped to standpipe	150,000 Ex. 6,500	1883
Fostoria (part)	7,070	Creek and impounded water	do	220,000 Ex. 3,500	1891
Findlay	18,553	Blanchard River	Direct pumping (filtered)	337,000	1889
Gallipolis	4,498	Ohio River	Infiltration wells	88,000	1895
Greenfield	2,460	Paint Creek	Pumped to standpipe and direct	60,000 Ex. 3,000	1891
Ironton	10,929	Ohio River	Direct pumping	175,000 Ex. 10,000	1871
Kent	3,501	Plum Creek and infiltration	Pumped to standpipe and direct	200,000	1887
Lancaster	7,555	Gallery and well from springs	Pumped to standpipe	70,000 Ex. 2,260	1882
Leetonia (M)	2,826	Spring and collecting basin	Direct pumping	11,000	1889
Loraine (M)	4,863	Lake Erie	Pumped to standpipe and direct	130,000	1884
Milford Center (M)	718	Springs	Direct pumping	12,000	1895
Martins Ferry	6,250	Ohio River	Direct and to reservoir	145,000 Ex. 6,000	1854
Marietta	8,272	do	Pumped to reservoir	110,000 Ex. 5,000	1890
Minerva (M)	1,139	Infiltration wells by Sandy Creek	Pumped to tank	15,000	1886
Milan	627	Huron River	Direct pumping	17,000 Ex. 1,800	1888
Marion	8,327	Infiltration wells from Little Scioto	Pumped to standpipe and direct	200,000	1890
Napoleon	2,764	Maumee River	do	60,000	1895
New Lisbon (75 per cent)	2,278	Little Beaver River	Pumped to reservoir. (See Wells in rock)	25,000 Ex. 1,500	1888

a "Ex." in this column means running expenses per annum.

Cities in Ohio using surface water for waterworks—Continued.

Name.	Population in 1890.	Supply.	Waterworks.		
			System.	Cost (to 1895). *a*	When put in.
Norwalk (M)	7,195	Impounded water (Huron River and creeks)	Direct pumping	$150,000 Ex. 6,000	1871
Nelsonville	4,558	Infiltration well	Pumped to reservoir	45,000	1895
Oberlin	4,370	East Vermilion River, storage reservoirs	Pumped to standpipe or direct	70,000 Ex. 1,550	1887
Ottawa (part)	1,717	Blanchard River	Fire cisterns only		
Painesville *b*	4,755	Lake Erie	Pumping to standpipe and direct	250,000	1882
Piqua	9,090	Canal system, with reservoirs	Direct pumping	400,000	1875
Port Clinton	2,049	Lake Erie	do	42,000	1895
Portsmouth	12,394	Ohio River	do	300,000	1871
Ripley	2,483	Settling basins from Ohio River	Pumped to reservoir	21,000	1896
Ravenna (part)	3,417	Crystal Lake	Direct pumping	170,000 Ex. 3,300	1885
Steubenville	13,394	Ohio River	Pumped to reservoir	*c* 200,000 Ex. 9,000	1835 1894
Sandusky	18,471	Sandusky Bay	Pumped to standpipe	525,000 Ex. 13,000	1875
Shelby (M.)	1,977	Impounded water	do	21,000	1897
Sidney	4,850	Great Miami River	do	100,000 Ex. 5,000	1873 1888
Tiffin (part)	10,801	Sandusky River and wells	Direct pumping	(?)	1878
Toledo	81,434	Maumee River	Pumped to standpipe	1,500,000 Ex. 38,000	1874
Toronto	3,536	Ohio River	Pumped to reservoir	75,000 Ex. 2,000	1891
Troy	4,494	Infiltration wells	Direct pumping	150,000 Ex. 2,250	1888
Uhrichsville	3,842	Stillwater Creek	Pumped to reservoir		1888

a "Ex." in this column means running expenses per annum. *b* Including Richmond and Fairport. *c* Cost of new system introduced in 1894.

Cities in Ohio using surface water for waterworks—Continued.

Name.	Population in 1890.	Supply.	Waterworks.		
			System.	Cost (to 1895). *b*	When put in.
Upper Sandusky	3,572	Sandusky River and springs	Pumped to standpipe	$60,000 Ex. 3,000	1890
Urbana (part)	6,510	Springs in east part of city *a*			
Wadsworth (part)	1,574	Springs	Gravity	20,000	1880
Warren (M.)	5,973	Mahoning River	Pumped to standpipe and direct	180,000	1887
Wellsville	5,247	Ohio River	Pumped to reservoir	60,000	1881
Wellston (M.)	4,377	Raccoon Creek	Pumped to standpipe	60,000	1891
Willoughby	1,219	Chagrin River, infiltration well	Pumped to reservoir	30,000 Ex. 1,500	1892
Wooster (part)	5,901	Impounded water and wells	do		1869
Xenia	7,301	Springs, impounded water	Pumped to standpipe	183,000 Ex. 4,500	1887
Youngstown	33,220	Mahoning River	Pumped to standpipe and direct	475,000 Ex. 18,000	1872
Zanesville	21,009	Muskingum River	Pumped to reservoir	500,000 Ex. 19,500	1842

a See "Wells in glacial drift," p. 526.
b "Ex." in this column means running expenses per annum.

SHALLOW WELLS IN VALLEYS.

More than 100 cities of Indiana and Ohio are so situated in valleys that the most convenient source of water supply is from shallow wells sunk to the level of the stream. In many cases the wells reach no lower than the alluvial deposits of the valley, but in some cases they pass through glacial deposits beneath the level of the stream bed, penetrating sometimes a thick bed of clay or a nearly impervious stratum above the beds which yield the water. It is difficult to determine what proportion of the water supply in valley wells is polluted, but the danger of pollution is certainly great, and such wells should be subjected to frequent examination and promptly abandoned when found to be polluted. Those cities which obtain a supply for waterworks from beds of alluvium usually take the precaution to locate the wells on the upstream side of the city, where danger from contamination will be at a minimum. Such wells are much safer than the private wells sunk within the city limits.

In the following table, which embraces the principal towns deriving water from the shallow wells in valleys, the general nature of the cover or beds overlying the water-bearing stratum is indicated. In cases where the cover is noted to be "imperfect" there appears to be nothing to prevent surface filth from reaching the water bed. In the cases marked "doubtful" there are some indications of protection from contamination, either by the presence of a nearly impervious stratum where wells are shallow, or by the distance to the water bed where wells are comparatively deep. In cases marked "fair" there is thought to be very little danger of contamination, for the water horizon is either too deep to be within the reach of such pollution within the city limits or is known to be beneath a practically continuous sheet of an impervious clay. The only apparent danger arises from lack of continuity in this impervious cover. In cases where the water cover is said to be "good" there appears to be no ground for suspicion of surface contamination of any kind. A word seems necessary at this point concerning a careless pollution of wells. It is found that in places where wells would be otherwise free from contamination pollution is frequently introduced by throwing slops and refuse matter around the well mouth, where it can scarcely escape filtration into the well.

Cities and villages of Indiana using shallow wells in valleys.

Place.	Population in 1890.	Depth. a	Water bed.	Cover.	Waterworks.		
					Cost (to 1895). b	System.	When put in.
		Feet.					
Brookville	2,028	20–110	Gravel	Doubtful to fair		See "Surface water"	
Clinton	1,365	20–75	do	do		None	
Connersville	4,548	12–30 60–80	do do	Doubtful Good		See "Surface water"	
Covington	1,891	50	do	Fair		do	
Edinburg	2,031	15–60 W. W. 19	do do	Doubtful do	$21,000 Ex. 900	Pumped to standpipe and direct	1893
Elkhart	11,360	25–100 W. W. 34	do do	Fair do	(?)	Pumped to standpipe	1883
Goshen	6,033	W. W. 34	Sand	do	90,000 Ex. 10,300	Direct pumping	1881
Hammond	5,428	6–18	do	Imperfect		See "Surface water"	
Huntington	7,328	30	Gravel or rock	Doubtful		See "Wells in rock"	
Indianapolis (75 per cent)	105,436	30–45 65–125	Gravel do	Imperfect Good		Direct pressure	1870
Jeffersonville	10,666	40–50	do	Doubtful		See "Surface water"	
Jonesville	(?)	20–30	do	do		None	
Knox	790	14–40	Sand	Imperfect		do	
Kouts	(?)	25–35	do	Fair		do	
Lake	(?)	20–25	do	Doubtful		do	
Ligonier	2,195	W. W. 34	do	Fair	32,000 Ex. 1,400	Pumped to standpipe and direct	1889
Liverpool	(?)	10–16	do	Doubtful		None	
Logansport (part)	13,328	12–40	Gravel	Imperfect		See "Surface water"	
Martinsville	2,680	W. W. 30 40–60	do do	Doubtful Good	25,000	Direct pumping	1894
Mishawaka	3,371	20	do	Doubtful		See "Surface water"	

a "W. W." in this column means that the well is a waterworks well.

b "Ex." in this column means running expenses per annum.

Cities and villages of Indiana using shallow wells in valleys—Continued.

Place.	Population in 1890.	Depth.[a]	Water bed.	Cover.	Waterworks.		
					Cost (to 1895).[b]	System.	When put in.
		Feet.					
Montezuma	658	30–70	Gravel	Imperfect to fair		None	
New Albany (part)	21,059	25–30	do	Imperfect		See "Surface water"	
Newcastle (W. W.)	2,697	90–250	do	Good	$27,000 Ex. 2,000	Direct pumping	1889
Nashville	395	12–35	Sand or rock	Imperfect to good		None	
New Harmony	1,197	20–25	Sand	Imperfect		do	
Noblesville	3,054	20–25 W. W. 65	Gravel do	do Good	$60,000 Ex. 200	Direct pumping	1891
North Judson	572	10–30	Sand	Imperfect		None	
Peru	7,028	15–60	Gravel	Imperfect to good		See "Surface water"	
Plymouth	2,723	W. W. 42	do	Good	17,000 Ex. 3,000	Direct pumping	1888
Quincy	(?)	20–30	Sand	Doubtful		None	
Rising Sun	1,689	60–120	Gravel	Fair		do	
Rosedale		12–25	Sand	do		do	
Rochester	2,467	16–20	do	do	35,000	Pumped to standpipe and direct	1893
Seymour	5,337	10–15 50	do do	Imperfect Good		See "Surface water"	
Shoals	738	18–90	Sand or sandstone	Doubtful		None	
Shelbyville	5,451	33	Gravel	Fair	225,000	Pumped to standpipe	
South Bend (W. W.) (62 wells).	21,819	100–125	do	Good	270,000 Ex. 20,000	do	1873
Spencer	1,868	20–80	do	Imperfect to fair		None	
Tell City	2,094	45–50	Sand	Fair		Fire cisterns only	
Terre Haute	30,217	30–50	Gravel	Imperfect		See "Surface water"	
Vevay	1,663	60–80	do	Fair		do	
Vincennes	8,853	20	Sand	Imperfect		do	
Walkerton	885	20–30	Gravel	Fair		None	
West Lafayette (M.)	1,242	(?)	(?)	(?)	61,000	Pumped to standpipe	1894
Worthington	1,448	15–40	Sand	Doubtful		None	

[a] "W. W." in this column means that the well is a waterworks well.

[b] "Ex." in this column means running expenses per annum.

Cities and villages of Ohio using shallow wells in valleys.

Place.	Population in 1890.	Depth. *a*	Water bed.	Cover.	Waterworks.		
					Cost (to 1895). *b*	System.	When put in.
		Feet.					
Ashtabula (part)	8,338	8-20	Gravel	Imperfect		See "Surface water"	
Ashland (part)	3,566	20-60	Gravel or shale	Fair	$45,000 Ex. 1,800	Pumped to standpipe and direct	1895
Bainbridge		30	Gravel	Imperfect		None	
Batavia	953	15-45	Gravel or sand	do		do	
Bellville	941	30	Gravel	do		do	
Bellaire	9,934	60-100	Gravel or sand	do		See "Surface water"	
Coshocton	3,672	30-35	Gravel	do	80,000	Pumped to reservoir	1890
Camden	846	12-30	do	do		None	
Canal Dover	3,470	35-52 W. W. 52	do do	Doubtful Fair	35,000	Pumped to standpipe	1895
Circleville (part)	6,556	25-35	do	do		See "Surface water"	
Dennison	2,925	12-40	Sand	Imperfect		do	
Defiance (part)	7,604	10-15 40-50	Gravel do	do Good		do	
Dresden	1,247	40	do	Doubtful		None	
Dayton	61,220	35-60	do	do	1,300,000 Ex. 36,000	Direct pumping	1869
Degraff	1,076	15-20 60-80	do	do		None	
Elyria	5,611	10-30 60-90	Sand do	do Good		See "Surface water"	1879
Eaton	2,934	W. W. 75	Gravel	do	80,000 Ex. 1,800	Pumped to standpipe and direct	1891
Fremont (part)	7,141	15-25	Sand	Doubtful		See "Surface water"	
Franklin	2,729	20-30 W. W. 70	do do	do Good	45,000 Ex. 3,000	Holly system	1888

a "W. W." in this column means that the well is a waterworks well. *b* "Ex." in this column means running expenses per annum.

Cities and villages of Ohio using shallow wells in valleys—Continued.

Place.	Population in 1890.	Depth. *a*	Water bed.	Cover.	Waterworks.		
					Cost (to 1895). *b*	System.	When put in.
		Feet.					
Germantown	1,437	20–25	Gravel	Doubtful		None	
Granville (M.)	1,366	(?)	do	Fair	$18,000	Pumped to tank	1885
Hamilton	17,565	45	do	do	360,000 Ex. 20,000	Pumped to reservoir and direct	1884
Harrison	2,010	25	do	Doubtful	55,000	Pumped to standpipe	1891
Hillsboro	3,620	(?)	do	Fair	80,000	Pumped to standpipe and direct	1895
Kent	3,501	18–25	do	Doubtful		do	1887
Lancaster	7,555	35–40	do	Fair		See "Surface water"	
Lockbourne		10–20	do	Doubtful		None	
Lodi	568	15–25	do	do		See "Surface water"	
Logan (waterworks)	3,119	35	do	Fair	35,000	Direct pumping	1896
Lynchburg (M.)	703	W. W. 16 14–20	do Gravel or rock	Doubtful do	16,000	Pumped to tank	1896
Manchester	1,965	80–140	Sand	Fair			
Mansfield	13,473	40–60 W. W. 140	Gravel Sandstone	do Good	325,000	Direct pumping	1870
McConnellsville	1,771	20–80	Gravel	Doubtful		None	
Martins Ferry	6,250	25–75	do	Imperfect		See "Surface water"	
Marietta	8,272	30–90	do	do		do	
Marion	8,327	10–15	do	Fair		Pumped to standpipe and direct	1889
Middleport	3,211	20–110	do	Doubtful to fair		None	
Middletown	7,681	33	do	Doubtful	75,000 Ex. 3,500	Direct pumping	1873
Milan	627	12–14	do	do		See "Surface water"	
Millersburg	1,923	W. W. 24 10–30	do	do	23,000	Direct pumping	1896
Morrow	842	15–35	do	do		do	

a "W. W." in this column means that the well is a waterworks well.

b "Ex." in this column means running expenses per annum.

Cities and villages of Ohio using shallow wells in valleys—Continued.

Place.	Population in 1890.	Depth. *a*	Water bed.	Cover.	Waterworks.		
					Cost (to 1895). *b*	System.	When put in.
		Feet.					
Moscow	591	40–60	Gravel	Doubtful to fair		Direct pumping	
Mount Vernon	6,027	17–20 W. W. 63–97	do do	Doubtful Good	$75,000	Pumped to standpipe	1882
Napoleon	2,764	15–30	do	Fair		See "Surface water"	
Navarre	1,010	18–65	Sand	Doubtful to fair		None	
Newark	14,270	15–30	Gravel	Doubtful	(?)	Pumped to reservoir	1885
Nelsonville	4,558	25	do	Fair	45,000	do	1894
New Comerstown	1,251	20–30	do	Doubtful		None	
New Philadelphia	4,456	20–50	do	do	(?)	Pumped to reservoir	1886
New Richmond	2,379	28–72	do	Doubtful to fair		None	
Niles	4,289	40–60	do	Fair	70,000	Pumped to reservoir	1891
North Lewisburg	866	10–15	do	Doubtful		None	
Osborne (M.)	713	18	do	Imperfect	22,000	Pumped to standpipe	1896
Oxford (M.)	1,922	(?)	(?)	(?)	36,000	Direct pumping	1896
Piqua	9,090	10–25	Gravel	Doubtful		See "Surface water"	
Pomeroy	4,726	60–65	Sand	do		None	
Ripley	2,483	60–70	do	Fair		See "Surface water"	
Springfield	31,895	15–20 W. W. 70	Gravel do	Imperfect Good	650,000 Ex. 16,500	Pumped to standpipe	1886
Troy	4,494	15–50	do	Doubtful to fair	150,000 Ex. 2,250	Direct pumping	1886
Uhrichsville	3,842	20	Sand	Doubtful		Pumped to reservoir. (See "Dennison")	
Waverly	1,567	45–65	Gravel	Fair		None	
Wellsville	5,247	16–50	do	Imperfect		See "Surface water"	
West Liberty		14–18	do	do		None	
Waynesville		15–30	do	Doubtful		do	
Zanesville	21,009	10–50	do	do		See "Surface water"	

a. "W. W." in this column means that the well is a waterworks well. *b.* "Ex." in this column means running expenses per annum.

WELLS IN GLACIAL DRIFT.

Within the glaciated portions of Indiana and Ohio a large number of cities and villages obtain their entire supply of water from the glacial drift. Water-bearing beds of gravel or sand are in many towns adequate to supply a waterworks system, and the quality of water furnished is usually superior either to surface water or to water from wells in the rock. There is less danger of pollution than in the wells of similar depth in the valleys, noted in the preceding table, for the cover is generally a compact bowlder clay. There is also less concentration of water than in the valleys, and consequently less danger of surface contamination being distributed to the wells in the neighborhood. In the following table, which embraces the principal towns depending upon wells in glacial drift, the character of the cover is indicated, as in the preceding table. It will be observed that very few instances have been found in which the cover appears to be imperfect or of doubtful protection from surface contamination. It will be noted that in some cities water is obtained at two horizons, and that in some cases the upper horizon has a doubtful cover, while the lower has a good cover. The advisability of sinking to the lower stratum is coming to be recognized in such towns, and the shallow wells are rapidly going out of use.

Cities and villages in Indiana using wells in glacial drift.

Place.	Population in 1890.	Depth. *a*	Water bed.	Cover.	Waterworks.		
					Cost (to 1895). *b*	System.	When put in.
		Feet.					
Akron	(?)	10–14	Sand	Doubtful		None	
Albion	1,229	60–100	Gravel	Good	(?)	Direct pumping	1896
Amo		*40–50	Sand	Fair		None	
Anderson	10,741	35–100	Gravel			See "Surface water"	
Angola (M.)	1,840		do		$35,000	Direct pumping	1895
Atwood	840		do	Fair		None	
Auburn	2,415	20–30 150	do do	do Good		do	
Avilla (M.)	576	20–100	do	Fair	2,800	Pumped to tank	1890
Bloomingdale	431	12–60	Variable	Fair to good		None	
Brazil	5,905	W. W. 20	Gravel	Fair	125,000 Ex. 3,500	Direct pumping	1875
Bremen (M.)	1,076	40±	do	Good	15,500	Pumped to tank	1892
Brownstown	1,422	20	Sand	Doubtful		None	
Butler	2,521	20–35 85–150	Gravel do	Fair Good	16,000 Ex. 2,500	Direct pumping	1890
Cambridge City (M.)	1,782	(?)	do	(?)	?25,000	Direct pumping; also reservoir	1895
Chambersburg	(?)	30–35	do	Fair		None	
Charlestown	888	15–35	Sand	Good		do	
Chesterton	931	18–33	do	Doubtful		do	
Claypool	(?)	25	do	Fair		do	
Clayton	(?	10–25	Variable	do		do	
Coatsville	(?)	25–30	do	do		do	
Colfax	730	15–30	do	do		do	
Collins	(?)	75–80	Gravel	Good		do	

a "W. W." in this column means that the well is a waterworks well.

b "Ex." in this column means running expenses per annum.

Cities and villages in Indiana using wells in glacial drift—Continued.

Place.	Population in 1890.	Depth. *a*	Water bed.	Cover.	Waterworks.		
					Cost (to 1895). *b*	System.	When put in.
		Feet.					
Nappanee	1,493	W. W. 140	Gravel	Good	$10,000 Ex. 500	Pumped to tank	1892
New Carlisle (M.)	607	(?)	do	(?)	(?)	do	1879
New Haven	1,079	25–35	do	Fair		See "Wells in rock"	
Newport	551	12–88	Variable	Fair to good		None	
North Manchester	2,384	10–100 W. W. 100	do	Doubtful to good	35,000	Pumped to standpipe	1894
Osgood	841	9–15	Sand	Fair		None	
Oxford	808	14–20 55	do Gravel	Doubtful Good		do	
Parker	(?)	20–60	do	Fair to good		do	
Plainfield	909	35–40	do	Good		do	
Philadelphia	(?)	20±	do	Fair		do	
Portland (part)	3,725	14–30	do	Doubtful		See "Wells in rock"	
Princeton	3,676	20–25	do	Fair		See "Surface water"	
Red Key (part)	922	10–15	do	Doubtful		None	
Remington (part)	940	12–20	do	do		do	
Rensselaer (part)	1,455	75–120	do	Good		do	
Reynolds	348	10–25 75–120	Sand Gravel	Doubtful Good		do	
Richmond	16,608	12–40	Variable	Doubtful		See "Surface water"	
Roann	582	30±	Gravel	Fair		None	
Rockville	1,689	15–75	Variable	Fair to good		See "Wells in rock"	
Rockfield	(?)	15–25 50–60	do	do		None	
Royal Center	521	15–110	do	do		do	
Rushville	3,475	14–75	do	Fair	85,000	Direct pumping and reservoir	1896

a "W. W." in this column means that the well is a waterworks well.

b "Ex." in this column means running expenses per annum.

Cities and villages in Indiana using wells in glacial drift—Continued.

Place.	Population in 1890.	Depth. *a*	Water bed.	Cover.	Waterworks.		
					Cost (to 1895). *b*	System.	When put in.
		Feet.					
Scottsburg	618	15–35	Sand	Fair			
Shelbyville	5,451	W. W. 35	Gravel	Fair	$225,000	Pumped to standpipe	1890
Sheridan	1,134	15–50	Variable	Fair to good		None	
St. Paul	(?)	15–90	do	do		do	
South Whitley (M.)	720	65	Gravel	Fair	15,000	Direct pumping	1895
Sullivan	2,224	15–35	Variable	Doubtful to good		See "Surface water"	
Templeton	(?)	20–30	Gravel	Fair		None	
Thorntown	1,530	14–60	Variable	Fair to good		do	
Tipton	2,697	12–30 100–140	do Sand	Doubtful Good	35,000 Ex. 3,000	Direct pumping	1894
Union City	2,681	6–40 W. W. 32	Variable Gravel	Fair Good	60,000 Ex. 3,500	do	1873
Upland	*c* 1,000	20–30	do	Fair	6,000 Ex. 125	Pumped to tank	1895
Valparaiso	5,090	15–200	Variable	Doubtful to fair		See "Surface water"	
Veedersburg	930	20–70	do	Fair		None	
Wabash	5,105	W. W. 42–55	Gravel	Good	200,000	Pumped to standpipe	1886
Warsaw (part)	3,574	10–40 W. W. 140	Variable Gravel	Doubtful Good	60,000	Pumped to standpipe and direct	1886
Washington	6,064	12–30	Sand	Fair		See "Surface water"	
Waterloo	1,473	20–30 60–90	Gravel do	do Good		None	
Winamac	1,215	25–80	Variable	Fair		do	
Winchester	3,014	10–25	Gravel	Doubtful		do	
Westville	522	15–20	do	do		do	

a "W. W." in this column means that the well is a waterworks well. *b* "Ex." in this column means running expenses per annum. *c* Estimated.

Cities and villages of Ohio using wells from glacial drift.

Place.	Population in 1890.	Depth. *a*	Water bed.	Cover.	Waterworks.		
					Cost (to 1895). *b*	System.	When put in.
		Feet.					
Ada	2,079	25–40	Gravel or rock	Fair		None	
Akron	27,601	60–40	Gravel	do	$200,000	Pumped to reservoir	1880
Andover (part)	733	12–20	do	do		None	
Ansonia	676	9–18	do	do		do	
Archbold (part)	780	12–16	Variable	do		do	
Arlington Heights (M.)	222					Supplied from Reading waterworks	
Attica	682	6–20	Gravel	Doubtful	15,000	Pumped to standpipe	1895
Bond Hill (M.)	399	(?)	(?)	(?)	(?)	Supplied from St. Bernard waterworks	
Berea (part)	2,533	10–15	Variable	Doubtful		None	
Blanchester	1,196	10–30	do	Fair	20,000	Pumped to standpipe	1897
Bluffton	1,290	12–30	Gravel	do		See "Wells in rock"	
Bryan (M.)	3,068	(?)	(?)	(?)	39,000	Direct pumping	1893
Bucyrus (part)	5,974	10–50	Gravel	Fair	60,000; Ex. 5,180	do	1884
Canfield	675	10–25	Sand	do		None	
Cardington	1,428	13–25	Gravel	Doubtful		do	
Carthage (M.)	2,257	100±	Sand	Fair	25,000	Direct pumping	1890
Celina (part)	2,702	20	Gravel	do		See "Wells in rock"	
Chicago Junction	1,299	60–100	do	Good		None	
Clyde (part)	2,327	8–20	Sand	Imperfect		See "Wells in rock"	
Columbus (part)	88,150	10–15; W. W. 45±	do; Gravel	Doubtful; Good	3,000,000	See "Surface water"	1870
Delaware	8,224	20–30	do	Fair	175,000; Ex. 5,000	Pumped to standpipe and direct	1889
Delphos (part)	4,516	14	Sand	Doubtful		See "Wells in rock"	
Edgerton	967	20–60	Gravel	Fair to good		None	

a "W. W." in this column means that the well is a waterworks well. *b* "Ex." in this column means running expenses per annum.

Cities and villages of Ohio using wells from glacial drift—Continued.

Place.	Population in 1890.	Depth. *a*	Water bed.	Cover.	Waterworks.		
					Cost (to 1895). *b*	System.	When put in.
		Feet.					
Fort Recovery	1,186	10–18	Gravel	Fair		None	
Galion	6,326	20–90	Variable	Good	$100,000	Pumped to standpipe	1884
Geneva	2,194	10–15 30–40	Gravel do	Doubtful Good		None	
Glendale	1,444	175	Sand	do	35,000	Pumped to standpipe	1892
Greenfield (part)	2,460	12–30	Variable	Fair		See "Surface water"	
Greenville	5,473	52–62	Gravel	Good	82,000 Ex. 2,500	Pumped to standpipe and direct	1893
Greenwich (M.)	881	W. W. 24	do	Fair	12,000	Pumped to standpipe	1896
Hartwell	1,507	100 ±	Sand	Good		do	1893
Hicksville	2,141	18–30	Gravel	Doubtful	22,000 Ex. 800	Direct pumping	1890
Hudson (part)	1,143	10–15	do	Imperfect		None	
Kent	3,501	25	do	Doubtful		See "Surface water"	
Lebanon	3,050	20–90	Variable	Fair	50,000	Pumped to standpipe and direct	1896
Linwood (M.)		100 ±	Sand	Good	54,000	Pumped to high and low service reservoirs	1894
London	3,313	70–180	Variable	do	(?)	Pumped to standpipe and direct	1890
Lockland (M.)	2,447					Supplied from Reading waterworks	
Leesburg	617	20–35	Variable	Fair		None	
Loudonville	1,444	20 110	Gravel do	Doubtful Good		do	
Leipsic	1,353	8–15 90–115	Sand Rock (?)	do Doubtful		do	
Madisonville	2,214	18–25 140–150	Sand do	do Good	35,000 Ex. 1,500	Direct pumping	1892
Marysville	2,810	15–30	Gravel	Fair		See "Wells in rock"	
Martinsville	336	30–65	Variable	do		None	

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b "Ex." in this column means running expenses per annum.

Cities and villages of Ohio using wells from glacial drift—Continued.

Place.	Population in 1890.	Depth.	Water bed.	Cover.	Waterworks.		
					Cost (to 1895).	System.	When put in.
		Feet.					
Mechanicsburg	1,459	10–20 60–100	Sand Gravel	Doubtful Good		None	
Montpelier (M.)	1,293	(?)	(?)	(?)	$26,000	Pumped to standpipe	1895
Mount Gilead (part)	1,329	10–30	Variable	Fair	(?)	Under construction	1897
New Bremen (part)	1,239	12–15	Sand	do		None	
New London	1,036	25 75–100	Gravel Variable	do Good		do	
New Madison	478	20–25	Sand	Fair		do	
New Paris	842	12–30	Gravel	Doubtful		do	
New Washington	704	20–30	Sand	Fair		do	
Norwood (M.)	845 ±	200 ±	Sand (?)	Good	133,152	Pumped to standpipe	1894
Oak Hill	637	20	Sand	Doubtful		None	
Oberlin (part)	4,376	10–30	Variable	Fair		See "Surface water"	
Orrville (M.)	1,765	(?)	(?)	(?)	25,000	Direct pumping	1894
Ottawa (part)	1,717	7–32	Variable	Fair		None	
Painesville (part)	4,755	10–25	Gravel	Doubtful		See "Surface water"	
Pataskala	568	12–40	Variable	Fair		None	
Paulding	1,879	40	Sand	do		do	
Pemberville	843	30	Gravel	Good		do	
Plain City (part)	1,245	7–13	Sand	Doubtful		See "Wells in rock"	
Plymouth	1,133	15–20	do	do		None	
Ravenna (part)	3,417	15–30	Variable	Fair		See "Surface water"	
Reading *a*	3,021	155–160	Gravel	Good	45,000	Pumped to reservoir	(?)
Richwood	1,415	20–35	do	Fair		None	
St. Bernard (M.)	1,779	100 ±	Sand	Good	64,320	Pumped to standpipe	1894
Shelby	1,977	10–40	Gravel	Fair		See "Surface water"	

a Including Lockland and Arlington Heights in water supply.

Cities and villages of Ohio using wells from glacial drift—Continued.

Place.	Population in 1890.	Depth. *a*	Water bed.	Cover.	Waterworks.		
					Cost (to 1895). *b*	System.	When put in.
		Feet.					
Sidney (part)	4,850	12–30	Gravel	Fair		See "Surface water"	
South Charleston	1,041	15–35	Variable	do		None	
Spencerville	1,266	10–25	do	Doubtful		do	
Springfield (part)	31,895	35–45	do	Fair		See "Wells in valleys"	
St. Marys (part)	3,000	8–12	Gravel	Doubtful		See "Wells in rock"	
St. Paris	1,140	20–30	Variable	Fair		None	
Stryker (part)	1,017	10–25	do	do		do	
Swanton	508	10–12 60	Sand Gravel	Imperfect Good		do	
Sylvania	545	15–75	Variable	Fair		do	
Toledo (part)	81,434	18–30	Sand	Doubtful		See "Surface water"	
Urbana	6,510	15–65 W. W. 21	Variable	Fair	$175,000 Ex. 4,000	Direct pumping	1878
Utica	763	20–35	do	do		None	
Van Wert (part)	5,512	20	Sand	do		See "Wells in rock"	
Versailles	1,385	14–40	Variable	do		None	
Wauseon	2,060	15	Sand	Imperfect		do	
Wapakoneta	3,616	15–40 W.W.70–143	Gravel do	Fair Good	57,000	Pumped to standpipe and direct	1895
Washington	5,742	15–30	do	Fair	125,000	do	1889
Wellington	2,067	15–35	Variable	do		None	
West Carrollton (M.)	360	60	(?)	(?)	7,800	Direct pumping (?)	1895
Weston	845	60	Gravel	Good		None	
West Unity	872	100±	do	do		do	
Wilmington	3,079	15–35	Variable	Fair		do	
Wyoming	1,454	130–160	Sand	Good	43,000 Ex. 2,400	Pumped through mains to reservoir	1889
Xenia (part)	7,301	10–80	Variable	Fair to good		See "Surface water"	
Yellow Springs	1,375	25±	do	Fair		None	

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WELLS IN ROCK.

A large number of cities and villages, both in Indiana and in Ohio, obtain part of their water supply from wells in rock. In the unglaciated portions of these States, except along the principal river valleys, the wells are almost entirely obtained in rock. As the writer's study was confined mainly to the glaciated portions of these States, the data from the unglaciated portions are rather meager. In the unglaciated districts cisterns are largely used, as it is less expensive to collect water in this way than to drill wells, and the abundant rainfall makes this a reliable means for obtaining water.

In the following table such data concerning wells in rock as are available have been grouped under several heads. These data are made up in part from notes gathered when in the field and in part from the schedules for city water supply, which were filled out by city officials or other competent residents.

The depth of wells here given usually indicates the horizon at which the water is most abundant, but in some cases where water is found at various levels the range in the depth of wells is indicated. It will be observed that in some cities the waterworks supply is from a lower horizon than that of the private wells, but in many cases the public and private wells are from the same horizon.

The water bed and quality of water, it will be observed, bear a definite relationship, water found in limestone being always hard and in sandstone usually soft. A few chemical analyses have been made which furnish definite information concerning the quality of water. These appear on another page. In the absence of analyses the popular estimate of the quality of the water is given, which, though not very definite, has considerable value.

The capacity of the wells is usually estimated by city officials. When numbers are given there have in some cases been accurate measurements, but as a rule only estimates or rude measurements. Some effort was made to determine the size of wells, in order to learn their relation to the capacity, but very little information could be obtained. It may be stated, however, that wells drilled in the rock are usually not less than 4 inches and not more than 12 inches in diameter. The majority of which the size was reported are 6 to 8 inches in diameter.

In the table showing the head from the surface the numerals indicate the distance below the surface, except where + is prefixed, when it is above the surface. Where water stands within a foot or two of the well mouth the word "surface" is used to designate the head. Where wells overflow and the height to which water will rise is not known the word "overflow" is used. It is probable that most of the numerals indicate the average head of the wells, especially in cases where the wells can be lowered by pumping or where the head decreases in seasons of drought.

Cities and villages of Indiana obtaining part of water supply from wells in rock.

Place.	Population in 1890.	Depth.	Water bed.	Quality of water.	Capacity per minute.	Head from surface.	Waterworks.		
							Cost (to 1895). *a*	System.	When put in.
		Feet.			*Gallons.*	*Feet.*			
Alexandria	715	60	Limestone	Hard	(?)	30	$46,000	Pumped to standpipe	1895
Anderson (part) (1 well at waterworks).	10,741	800	(?)	Hard, iron	Unlimited	Overflows.	150,000	Direct pumping. (See "Surface water.")	1886
Andrews	1,320	60-150	Limestone	Analysis	Unlimited.	+5 to —14		None	
Bedford	3,351	90-100	do	Hard	Strong.	50		See "Surface water"	
Bloomfield	1,229	20-25 150-160	Sandstone	Soft	Strong.			None	
Bloomington	4,018	10-50	Limestone	Hard	Weak.	(?)		See "Surface water"	
Bluffton, waterworks (10 wells).	3,589	100-500	do	do	(?)	(?)		Direct pumping	1886
Butler, gas boring	2,521	600	do	Hard, pleasant	(?)	(?)		See "Wells in glacial drift"	
Charlestown	888	20-35	do	Hard	Weak.	5-15		None	
Columbia City, waterworks (3 wells).	3,027	280	do	Analysis	230	+5	30,000	Direct pumping	1893
Converse, waterworks	921	230	do	Hard	(?)	4	10,000	Pumped to tank	1895
Converse and vicinity	(?)	200-400	do	do	Strong.	Surface.			
Covington	1,891	350±	(?)	Sulphurous	Strong.	(?)		See "Surface water"	
Decatur, waterworks (8 wells).	3,142	250	Limestone	Hard	(?)	15	65,000	Storage well with direct pumping	1895
Dunkirk, waterworks	1,024	65-100	do	do	20	45	17,000 Ex. 1,100	Direct pumping	1894
Elwood, waterworks	2,284	75-150	do	Analysis	175	15-25	100,000	do	1892
Fairmount	1,462	15-30	do	Hard	(?)	6		See "Surface water"	
Fort Wayne, waterworks (about 30 wells).	35,393	250-450	do	do	90	Variable.	550,000 Ex. 13,000	Pumped to reservoir and direct. See "Wells in glacial drift"	1879
Fowler	1,285	175	do	do	150	25	36,500	Pumped to reservoir and direct	1895

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Cities and villages of Indiana obtaining part of water supply from wells in rock—Continued.

Place.	Population in 1890.	Depth.	Water bed.	Quality of water.	Capacity per minute.	Head from surface.	Waterworks.		
							Cost (to 1895). *a*	System.	When put in.
		Feet.			*Gallons.*	*Feet.*			
Francesville	403	40	Limestone	Hard	(?)	(?)		None	
Geneva	748	80	do	do	(?)	(?)		do	
Gosport		926	(?)	Sulphurous	Strong.	Overflows.		do	
Greenfield, waterworks	3,100	176	Limestone	Hard	150	Overflows.	$50,000 Ex. 2,500	Direct pumping	(?)
Greenwood (sanitarium)	862	1,725 600	do do	Sulpho-saline (?)	(?) (?)	240 45		None	
Greencastle (M.)	4,390	(?)	do	Hard	(?)	Overflows.	303,000	Pumped to standpipe	1886
Greensburg, waterworks	3,596	75	do	Analysis	200+	20	(?)	Direct pumping	1889
Harrodsburg	(?)	20-30 111-130	do do	Hard do	Weak. Strong.	Variable. 30		None	
Hartford	2,287	125-250	do	Sulphurous, hard.	8	10-20	50,000 Ex. 1,000	Direct pumping	1894
Huntington, waterworks (11 wells).	7,328	100±	do	Hard	2 each.	10	100,000	Direct pumping. (See "Surface water.")	1890
Indianapolis, waterworks (small part).	105,436	Various	do	Hard, iron	(?)	+5	2,500,000	Direct pumping. (See "Surface water" and "shallow wells.")	1870
Jasper	1,281	20-130	Sandstone	Variable	4	Surface.		See "Surface water"	
Jeffersonville	10,666	60±	Limestone	Hard	(?)	55		do	
Kentland (M.)	918	(?)	do	do	45	(?)	6,325	Pumped to tank	1896
Knightstown, waterworks (5 wells).	1,867	55-60	do	Iron, hard	15	14	28,000	Pumped to standpipe	1894
Kokomo, waterworks	8,261	100-150	do	Hard, sulphurous.	(?)	Surface.		Direct pumping	1887
Near Kokomo (Wolf well)		1,000±	(?)	(?)	500	Overflows.	(?)	Used in irrigation	
Lafayette	16,243	235 1,000	Limestone do	Sulphurous Sulphosaline	(?)	Overflows.		See "Surface water"	
Lodi	(?)	35± 1,155	do do	Analysis	Strong.	Overflows.			

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Cities and villages of Indiana obtaining part of water supply from wells in rock—Continued.

Place.	Population in 1890.	Depth.	Water bed.	Quality of water.	Capacity per minute.	Head from surface.	Waterworks.		
							Cost (to 1895). *a*	System.	When put in.
		Feet.			*Gallons.*	*Feet.*			
Logansport (small part)	13,328	70–80	Limestone	Hard, sulphurous.	(?)	4–8		Direct pumping. (See "Surface water.")	1875
Marion, waterworks	8,769	240	do	Hard	100	Overflows.	Ex. $5,000	Direct pumping	1877
Martinsville (sanitariums)	2,680	675 1,490	Variable	Analysis	30–85	Overflows.		See "Shallow wells"	
Michigan City (3 wells)	10,776	541 819 833	Limestone	Hard, sulphurous.	300±	Overflow.			
Mitchell	1,583	30–100 1,200	do (?)	Hard Saline	(?) (?)	(?) Surface.		None Drawn for street sprinkling.	
Montpelier (M.)	808	(?)	(?)	Hard	(?)	Overflows.	41,000	Pumped direct from collecting basins.	1896
Monon	1,064	20–200	Limestone	Sulphurous and hard.	(?)	(?)		None	
Montezuma (Riverside Hotel).	658	1,675	do	Analysis	Strong.	+115			
Muncie (M.)	11,345	(?)	do	Hard	500	+ 10		Direct pumping	1885
New Haven, waterworks	1,079	300±	do	Analysis	Strong.	+ 10	9,000	do	1893
Noblesville	3,054	65–80	do	Hard	Strong.	6	Ex. 1,000	See "Wells in valleys"	
North Vernon	2,012	12–35	do	do	Weak.	2–15		See "Surface water"	
Near North Vernon	(?)	66	do	do	Strong.	Overflows.			
Oakland City	1,524	20–60	Sandstone or shale.	Iron sulphate	(?)	10–0		None	
Paxton		25–30	Sandstone	Sulphurous	(?)	(?)		do	
Portland	3,725	25–150	Limestone	Hard, sulphurous.	250	10–15	45,000	Direct pumping	1892
Red Key	922	70–100	do	Hard	(?)	20		None	
Remington	940	75–125	do	Sulphurous, hard	8	20±		do	
Rensselaer	1,455	30–200	do	do	Strong.	Surface.		do	
Richmond	16,608	12–40	do	Sulphates, hard	1–5	Variable.		See "Surface water"	

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Cities and villages of Indiana obtaining part of water supply from wells in rock—Continued.

Place.	Population in 1890.	Depth.	Water bed.	Quality of water.	Capacity per minute.	Head from surface.	Waterworks.		
							Cost (to 1895).	System.	When put in.
		Feet.			*Gallons.*	*Feet.*			
Ridgeville	922	30–40	Limestone	Hard	10–15	10±		None	
Rockport	2,314	20–100	Sandstone	Soft	(?)	(?)		See "Surface water"	
Rockville, waterworks (4 wells).	1,689	100–208	(?)		Weak.	(?)	$20,000	Under construction	1897
Salem	1,975	20–60	Limestone	Hard	(?)	10–40		See "Surface water"	
St. Paul		75–90	do	Sulphurous	(?)	(?)		None	
Seymour (gas boring)	5,837	1,194	do	Sulphurous, hard, saline.	(?)	Overflows.		See "Surface water"	
Shoals	738	900	(?)	Analysis	Weak.	Overflows.		None	
Spencer (3 wells)	1,868	1,150±	Limestone	do	Strong.	Overflow.		do	
Sullivan and vicinity	2,222	100–400	Sandstone	Pleasant	(?)	(?)		See "Surface water"	
Sullivan (gas well)		1,000±	(?)	Saline	(?)	15		Pumped for street sprinkling	
Versailles	421	18–25	Limestone	Hard	1–5			None	
Wabash (artesian well)	5,105	2,270	do	do	(?)	85		See "Wells in glacial drift"	
Williamsport	1,027	65	(?)	Fresh	(?)	(?)		None	
Williamsport (gas boring)		1,200	(?)	Saline	(?)	(?)		do	
Winamac (gas well)	1,215	1,200	Sandstone	Saline, iron	45	(?)		do	
Winchester	3,014	100±	Limestone	Hard	Strong.	10		do	
Worthington	1,448*	1,445	(?)	Sulphurous	Strong.	Overflows.		do	

Cities and villages of Ohio obtaining part of water supply from wells in rock.

Place.	Population in 1890.	Depth. *a*	Water bed.	Quality of water.	Capacity per minute.	Head from surface.	Waterworks.		
							Cost (to 1895). *b*	System.	When put in.
		Feet.			*Gallons.*	*Feet.*			
Ada (part)	2,079	25–40	Limestone	Hard	(?)	8–15		None	
Andover	733	40–60	Berea grit	Soft	360	16		do	
Archbold	780	160–175	Limestone	Hard	Strong.	10		do	
Ashland	3,566	30–90	Sandy shale.	Soft	(?)	(?)	$45,000 Ex. 2,400	Pumped to standpipe and direct.	1895
Athens (part)	2,620	20–50	Sandstone	do	(?)	(?)		See "Surface water"	
Bellefontaine (2 wells)	4,245	164	(?)	Analysis	350	+4	128,000 Ex. 5,000	Pumped to reservoir	1883
Belmore	414	60–70	Limestone	Hard, sulphurous.	(?)	10–20		None	
Berea	2,533	60±	Berea grit	Iron	Variable.	50		do	
Blanchester	1,196	30±	Limestone	Hard	(?)	10–15	20,000	Pumped to standpipe	
Bluffton	1,290	12–33	do	do	Variable.	10–20	18,000	Pumped to standpipe and direct.	1896
Bowerstown	(?)	16–65	Sandstone	Hard and soft	(?)	(?)		do	
Bowling Green	3,467	70–200	Limestone	Hard, sulphurous.	Strong.	15	70,000 Ex. 4,000	do	1893
Cadiz	1,716	W. W. 200 20–40	Sandstone Limestone	(?) Hard	Strong. (?)	(?) (?)	35,000 Ex. 2,000	Direct pumping	1895
Cambridge	4,361	30±	Soft sandstone.	Soft, sulphurous	(?)	20		See "Surface water"	
Canfield	675	50–75+	Sandstone	Sulphurous	(?)	(?)		None	
Canton (part) (36 wells)	26,189	275–385	Limestone and sandstone.	Hard	50	Overflow.	450,000 Ex. 24,000	Direct pumping	1869
Carey (M.)	1,605	W. W. 60	Limestone	do	(?)	(?)	28,000	Pumped to standpipe	1895
Castalia	(?)	30–60	do	Sulphurous	3	30	(?)	Tank and hose for fire	(?)
Carrollton (M.)	1,228	W. W. 100	(?)	Hard	(?)	(?)	25,500	Pumped to standpipe	1896
Cedarville	1,355	25–30	Limestone	Sulphurous	Variable.	15	Ex. 600	None	

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Cities and villages of Ohio obtaining part of water supply from wells in rock—Continued.

Place.	Population in 1890.	Depth.a	Water bed.	Quality of water.	Capacity per minute.	Head from surface.	Waterworks.		
							Cost (to 1895).b	System.	When put in.
		Feet.			*Gallons.*	*Feet.*			
Celina	2,702	250±	Limestone	Fresh, hard	40	Near surface.	$50,000 Ex. 1,200	Pumped to standpipe and direct.	1895
Celina (deep wells)		1,100 1,700	(?) (?)	Saline Sulphurous	(?) (?)				
Clyde	2,327	65	Limestone	Hard	3-6	6	37,000 Ex. 2,000	Direct pumping	1883
Near Clyde		50-75	do	Hard, iron, sulphur.	5-15	Overflows.			
Corning (M.)	1,551	25-45	Sandstone	(?)	(?)	(?)	10,000	Pumped to tanks for fire protection.	(?)
Columbiana	1,112	20-30 W. W. 30 by 35.	do	Not hard	Variable.	Surface.	30,000 Ex. 1,200	Direct pumping	1895
Continental (M.)	895	(?)	Limestone	Hard	(?)	(?)	4,000	Pumped to tank	1894
Covington	1,778	10-50	do	do	(?)	6-12		None	
Cuyahoga Falls	2,614	50±	Sandstone	Soft	Variable.	25			
Delaware (artesian well)	8,224	2,250	Several	Hard, saline, sulphurous.	10	Overflows.		See "Wells in glacial drift"	
Delphos	4,516	35-50	Limestone	Hard	Variable.	4-5	65,000	Pumped to standpipe	1896
Deshler	1,114	70-95	do	do	Strong.	20		None	
Doylestown	1,131	10-50	Sandstone	Soft	(?)	6-8		do	
Dunkirk	1,220	100±	Limestone	Hard	Strong.	Near surface.		do	
East Palestine (M.)	1,816	(?)	Sandstone	Soft	Strong.	(?)	23,500	Pumped through mains to reservoir.	1890
Elyria	5,611	60-90	do	"Alum" water	Strong.	16		See "Surface water"	
Findlay	18,553	30-100	Limestone	Hard, sulphurous.	(?)	5-15		do	
Forest	1,126	90±	do	Hard	(?)	5-15		None	
Forest (3 miles southwest of).		480	do	"Whitesulphur".	Strong.	Overflows.		Forced to tank for domestic and stock use.	
Fostoria	7,070	30-50	do	Hard	(?)	20		See "Surface water"	

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Cities and villages of Ohio obtaining part of water supply from wells in rock—Continued.

Place.	Population in 1890.	Depth.	Water bed.	Quality of water.	Capacity per minute.	Head from surface.	Waterworks.		
							Cost (to 1895). a	System.	When put in.
		Feet.			*Gallons.*	*Feet.*			
Fremont	7,141	40-60	Limestone	Hard, sulphur	15-20	25		See "Surface water"	
Galion	6,326	90±	Sandstone	(?)	35	5-13		Pumped to standpipe	1882
Gambier	660	17-90	Freestone	Soft and hard		6±		None	
Grand Rapids	572	40-60	Limestone	Hard, sulphurous.	(?)	10-15		do	
Greenfield	2,460	25-30+	(?)	Hard	(?)	8-12		See "Surface water"	
Hanoverton	366	14-35	Sandstone	Soft, sulphurous	15-20	4-12		None	
Hillsboro	3,620	10-50	Limestone	Hard	(?)	Variable.		See "Shallow wells in valleys"	
Jackson	4,320	18-25	Sandstone	(?)	Weak.	6-10		None	
Kent	3,501	75-100	do	Soft	(?)	(?)		See "Surface water"	
Kenton, waterworks	5,557	100	Limestone	Hard	Strong.	15	$90,000	Direct pumping	1881
Larue	948	50-100	do	Hard, sulphurous.	Strong.	10-20		Railway pumps from Scioto River	
Lima	15,987	140-148	do	do	550	Overflow.	338,000 / Ex. 12,000	Direct pumping	1885
Louisville (M)	1,323	(?)	(?)	(?)	(?)	(?)	15,000	Pumped to standpipe	1895
Mansfield	13,473	100-140	Sandstone		Strong.	Overflow.	125,000	Direct pumping	1870
Marion	8,327	50-75	Limestone	Hard	15	10-40		See "Surface water"	
Martinsville	336	350±	do	Pure	(?)	Near surface.		None	
Marysville	2,810	18-80	do	Hard		6-10	80,000	Direct pumping	1890
Massillon	10,092	100-200	Sandstone	Analysis	350	Overflow.	200,000	Pumped to standpipe and direct.	1854 / 1885 / 1891
Medina	2,073	30-100	Limestone	Hard, sulphur	Weak.	(?)	5,000 / Ex. 600	Pumped to standpipe	
Mendon	400	50±	do	Hard, sulphurous.	Variable.	2-20		None	
Morrow	842	50	do	Hard	Strong.	35		do	
Mount Sterling (M)	752	(?)	do	do	(?)	(?)	12,000	Pumped to reservoir and direct.	1896
Mount Gilead	1,329	140±	Sandstone	Unpleasant	(?)	40	(?)	Under construction	1897

a "Ex." in this column means running expenses per annum.

Cities and villages of Ohio obtaining part of water supply from wells in rock—Continued.

Place.	Population in 1890.	Depth. *a*	Water bed.	Quality of water.	Capacity per minute.	Head from surface.	Waterworks.		
							Cost (to 1895). *b*	System.	When put in
		Feet.			*Gallons.*	*Feet.*			
Napoleon	2,764	114-130 1,600-1,800	Limestone (?)	Sulphurous do	Variable. (?)	20 +3		See "Surface water"	
New Bremen	1,239	70-100	Limestone	Hard	(?)	10-15		None	
New Lisbon, waterworks (25 per cent).	2,278	50-80	Sandstone	Soft	30	20	$25,000	Pumped to reservoir. (See "Surface water)".	1840 1888
New London	1,036	150±	Berea grit	Saline				None	
New Paris	842	20-30	Limestone	Hard	(?)	2-5		do	
New Straitsville	2,782	20-30	Variable	Hard, sulphurous.	(?)	10-12		Cisterns for fire; impounded water for mining industries, etc.	
North Baltimore	2,854	50-60	Limestone	Hard	(?)	(?)	75,000	Pumped to standpipe	1892
Oak Harbor	1,681	30-40	do	do	(?)	20-30		None	
Oak Hill	657	50	(?)	Hard, iron	(?)	5-10		do	
Ohio City	666	75	Limestone	Hard	Strong.	25		do	
Ottawa	1,717	130±	do	Hard, sulphurous.	Strong.	14		Public wells	
Paulding	1,879	40?	do	Hard	10-25	8-10		None	
Perrysville (M)	522	92	(?)	(?)	(?)	(?)	6,000	Pumped to reservoir	1895
Perrysburg	1,747	80	(?)	Hard	Strong.	40		None	
Plain City (2 wells)	1,245	500±	(?)	Hard, sulphurous.	Strong.	+12	23,000 Ex. 1,584	Direct pumping	1894
Republic	584	60-90	Limestone	Hard, iron	(?)	30-40		None	
Richwood	1,415	35	do	Hard	(?)	15		do	
Ripley	2,483	615	Sandstone (?)	Analysis	Weak.	Overflows.		See "Surface water"	
Rockford (M)	(?)	(?)	(?)	(?)	(?)	(?)	13,500	Pumped to standpipe	1862
Salem, waterworks	5,780	100-110	(?)	Hard	(?)	18	150,000	Pumped to standpipe and direct. (See "Surface water").	1887
Salineville	2,369	40-60 W. W. 100±	Sandstone	(?)	(?)	10-25	40,000 Ex. 1,200	Pumped to reservoir	1892

a "W. W." in this column means that the well is a waterworks well.

b "Ex." in this column means running expenses per annum.

Cities and villages of Ohio obtaining part of water supply from wells in rock—Continued.

Place.	Population in 1890.	Depth. *a*	Water bed.	Quality of water.	Capacity per minute.	Head from surface.	Waterworks.		
							Cost (to 1895). *b*	System.	When put in.
		Feet.			*Gallons.*	*Feet.*			
Shreve, waterworks	1 012	140±	(?)	(?)	60	100	$8,000 Ex. 600	do	1893
Sidney	4,850	120 to 200±	Limestone	Hard	(?)	Overflow.		See "Surface water"	
Springfield	31,895	35-45	do	do	Variable.	Variable.		See "Wells in valleys"	
Stryker	1,017	100-160	Shale (?)	do	(?)	2-20		None	
St. Clairsville	1,191	50-100	Limestone	do	10	(?)		do	
St. Marys	3,000	W. W. 280	do	do	150-500	Overflows.	50,000	Direct pumping	1895
Swanton	508	60	Top of rock	do	Strong.	Surface.		None	
Sylvania	545	75±	Limestone	do	(?)	12		do	
Tiffin, waterworks (part) (7 wells).	10,801	70-150±	do	do	80 each.	Surface.		Direct pumping	1878
Upper Sandusky	3,572	65-70	do	Hard, sulphur	(?)	15-20		See "Surface water"	
Urbana, gas well	6,510	275	do	Hard	70-100	+33		See "Wells in glacial drift"	
Van Wert, waterworks (6 wells).	5,512	127-175	do	Hard, sulphurous.	150±	5-9	125,000 Ex. 4,000	Direct pumping	1890
Wadsworth	1,574	40-50	Sandstone	Soft	(?)	(?)		See "Surface water"	
Wauseon	2,060	150	Top of rock	Soft (?)	50	Overflows.		None	
Waynesville	704	20-30+	Limestone	Hard	(?)	(?)		do	
West Union	825	10-30	do	do	Weak.	10±		do	
West Unity	872	100-200	(?)	Sulphurous	40	Overflows to —28.		do	
Wilmington	3,079	60-100	Limestone	Hard	(?)	Overflow.		do	
Winchester	(?)	25	do	do	(?)	7-10		do	
Wooster	5,901	80-140	Shale	Hard, saline	(?)	(?)		See "Surface water"	
Xenia, waterworks (part) (2 wells).	7,301	57-100	Limestone	Hard	Weak.	(?)		do	
Yellow Springs	1,375	25-100	do	do	(?)	(?)		None	

a. "W. W." in this column means that the well is a waterworks well.

b. "Ex." in this column means running expenses per annum.

DETAILED OBSERVATIONS.

In many cases the conditions for obtaining water supplies can not well be stated in tabular form. It therefore seems necessary to supplement the tables by explanations covering such cases. The cities or villages thus discussed are taken in alphabetical order, first in Indiana and then in Ohio, and are not grouped as in the above tables.

INDIANA CITIES AND TOWNS.

Anderson, Indiana.—This city stands on the bluffs of White River, the part near the river being broken or rolling land, standing 75 to 100 feet above the stream, while the part back from the bluff is nearly level. In the central and eastern portions of the city water is found in gravel beds at an average depth of 35 feet, and has very little impervious clay above it. In the south and west parts of the city much blue bowlder clay is penetrated, and water is found at various depths, ranging from 50 to 100 feet or more. An artesian well located near the waterworks pumping station in White River Valley is discussed above (p. 487). (Information furnished by James T. Knowland, clerk of waterworks.)

Bloomington, Indiana.—This city obtains its supply for the waterworks from two large springs, the larger of which is called Stone spring. The water is collected in a reservoir, which receives more or less drainage from the surrounding country. The waterworks supply is not used for culinary purposes, the residences being furnished with cisterns and in a few instances with wells or springs. Situated as the city is on a driftless upland, these are its only resources. An artesian well drilled to a depth of 2,730 feet failed to obtain a suitable quantity or quality of water for city use. (Information obtained from C. E. Siebenthal and from State geological reports.)

Bluffton, Indiana.—There are about ten wells drawn upon by the waterworks, the majority of which are 100 to 200 feet in depth, but one well is 300 and another 500 feet. The water is very hard, but is otherwise unobjectionable. In seasons of drought the Wabash River is drawn upon to meet the extra demands for watering lawns, etc.

Brookville, Indiana.—The waterworks supply is obtained from two large open wells sunk in gravel within 30 feet of the edge of Whitewater River, about one-third of a mile above the corporate limits of the town. The wells are 24 feet in diameter and are sunk 12 feet below the lowest water in the river. The present consumption occasionally reaches 300,000 gallons per day. The sanitary analysis, made by Prof. H. A. Huston, State chemist, is as follows:

	Parts in 100,000.
Free ammonia	0.0106
Albuminoid ammonia	0.0888
Nitrogen in nitrates	None.
Nitrogen in nitrites	Trace.
Phosphates	Trace.
Bromine	None.

Hardness (Clark's scale) { Temporary, 5 degrees. Permanent, 9 degrees.

An analysis of the mineral ingredients is presented on another page. (Information furnished by John Burkhart, superintendent of waterworks.)

Columbia City, Indiana.—This city finds excellent water in gravel at a depth of about 75 feet, which supplies many private wells. At the waterworks there are three 8-inch wells 280 feet in depth, which enter limestone and have a united capacity of about 1,000,000 gallons per day. Temperature of water, 50.5° F. Chem-

ical analysis appears on another page. (Information furnished by J. M. Harrison, mayor.)

Covington, Indiana.—In the vicinity of this city there are numerous springs, both from gravel beds and underlying sandstone, some of which furnish the city water supply. There is also a well over 300 feet in depth, known as the "Artesian well," but which does not overflow. This yields an abundance of "sulphur water," and the city is taking steps toward bringing it into extensive use. (Information furnished by A. T. Livengood, mayor.)

Danville, Indiana.—This city obtains its water supply from four 2-inch and two 3-inch wells driven to a depth of 110 feet in the glacial drift. The water obtained is of medium hardness, with a little iron and sulphur, and has a head 26½ feet above the surface. The average flow of each well is about 2,000 barrels per day. (Information by C. C. Hadley, president town board.)

Elkhart, Indiana.—A large well 34 feet in depth and 27 feet in diameter, excavated in the glacial drift, will yield 2,000,000 gallons per day. There is a thin bed of clay overlying the water-bearing gravel which is thought to protect it from contamination. Many driven wells in the city obtain water at from 25 to 100 feet without entering rock. In these wells the head ranges from 3 feet above to 7 feet below the surface.

Evansville, Indiana.—The city water supply is obtained from the Ohio River by direct pumping. A new waterworks plant is being constructed and a general reconstruction of the system is being made. There are several deep borings in the city and vicinity, some of which supply water to parks and a natatorium. (Information furnished by August Pfafflin, city engineer.)

Fort Wayne, Indiana.—The public water supply is from 54 wells, about one-half in gravel, at a depth of 40 to 60 feet, and one-half in rock, at a depth of 250 to 450 feet. Capacity of wells 7,000,000 gallons per day. Pumping capacity 11,000,000 gallons per day. Probably 28,000 persons, or two-thirds of the population, are supplied from these wells. The remainder use private wells and cisterns. A sanitary analysis made by the city chemist, L. P. Drayer, is as follows:

	Parts in 100,000.
Total solids	9.32
Free ammonia	Trace.
Albuminoid ammonia	Trace.
Chlorides	0.35
Nitrogen in nitrates and nitrites	Trace.

Iron in minute quantities.

Bacteria per cubic centimeter, 210.

Occasionally a turbidity exists, due to particles of finely divided clay, but the water is generally clear. The wells in the drift have at least 7 feet of blue clay just above the gravel, which is thought to protect them from surface contamination. Several deep borings have been made in the city and vicinity in prospecting for natural gas, and one well was sunk for artesian water at the court-house square in 1875, but without obtaining a flow, though a depth of 3,000 feet was reached. The water furnished by these wells is not considered preferable to that now in use, and the expense of boring may be considered a total loss. One boring, near the bank of the Maumee River, in White's addition, overflows at the rate of 400 gallons a minute. The water is of excellent quality, but it is not utilized. (Information furnished by Prof. C. R. Dryer.)

Frankfort, Indiana.—The public water supply is obtained from six 8-inch wells, bored in the bottom of a reservoir sunk 28 feet in depth. The wells extend about 30 feet below the bottom of the reservoir. The capacity of the wells is found to be about 6,000,000 gallons per day. Three sanitary analyses of water were made by Prof. T. C. Van Nuys, of the State University, one specimen being taken from an

old well, another from a faucet in the engine house, and another from a new well. They show very little difference, and the average of the analyses is as follows:

	Parts in 100,000.
Total solids	34.64
Calcium oxide	8.55
Magnesium oxide	5.08
Organic matter	5.66
Chlorine	0.77
Ammonia	0.23
Nitric acid	0.15

Garrett, Indiana.—The following analysis of water at the wells of the Baltimore and Ohio Railway headquarters were furnished by E. J. Hughes, M. D.:

	Parts in 100,000.	
	35-foot well.	75-foot well.
Total solids	36.30	55.38
Chlorine	0.40	1.16
Free ammonia	0.071	0.003
Albuminoid ammonia	0.009	0.0029
Reaction	Alkaline.	Alkaline.
Turbidity	Turbid.	Clear.

This analysis apparently indicates contamination of the shallow well, and Dr. Hughes writes that the overlying beds are probably not sufficiently impervious to prevent contamination. The larger amount of chlorine in the deeper well is, perhaps, derived from mineral substances in the drift and is probably not due to surface contamination. The Manual of American Waterworks reports that waterworks constructed in 1896 obtain supply from four 8-inch wells; depth not noted.

Greensburg, Indiana.—The entire waterworks supply is from one well 75 feet deep and 12 inches in diameter, 50 feet in the drift and 25 feet in underlying limestone The main supply of water was struck at 21 feet in the rock. Here the drill dropped 10 inches, and drillings below this depth could not be pumped out. The average daily consumption from this well by the city and railway companies is estimated to be 7,500 barrels of 40 gallons. The well has been pumped at the rate of 2,000,000 gallons per day without any appreciable exhaustion, and it is thought that the well may be depended upon for this amount. The following sanitary analysis was made by Prof. E. G. Smith, of Beloit, Wisconsin:

	Parts in 100,000.
Free ammonia	0.066
Albuminoid ammonia	0.004
Chlorine	0.62
Nitrites	None.
Nitrates	Trace.
Hardness { Temporary, 11.5 degrees.	
Hardness { Permanent, 8.0 degrees.	
Hardness { Total, 19.5 degrees.	

An analysis of the mineral matter is given on another page, and shows calcium and magnesium carbonate to constitute the bulk of the mineral material. (Above data furnished by Prof. W. P. Shannon, of Greensburg, and Mr. William F. Ross, of Rochester, New York.)

Hammond, Indiana.—The public water supply for the city of Hammond is obtained

from pipes extended out beneath Lake Michigan. A 16-inch pipe, running about 1,600 feet into the lake, leads to a well or settling basin 10 feet in diameter and 30 feet deep. Another pipe, 24 inches in diameter, is extended 2,000 feet into Lake Michigan. This leads to a well 20 feet in diameter and 20 feet deep. The two wells are properly screened from surface contamination. This water has displaced the use of artesian wells, and supplies the locomotives for several railroads as well as the engines for several large factories, all of which had found the use of artesian water unsatisfactory. The private wells of Hammond are often obtained without passing through any impervious stratum, and it is thought much danger may arise from their use. The use of such water is being abandoned as the superior character of the public water supply comes to be recognized. (Information furnished by W. F. Bridge, city engineer.)

Huntington, Indiana.—Eleven wells have been sunk near the waterworks station to a depth of about 100 feet, but the supply being inadequate, water is also pumped from the Wabash River. A large part of the population still depend upon private wells, and the water thus obtained seems to be pure. (Information furnished by S. T. Cast, mayor.)

Indianapolis, Indiana.—The Indianapolis Water Company supplies also the suburbs West Indianapolis, Haughville, and Brightwood. It obtains about three-fourths of its supply from wells and one-fourth by filtration from White River. Both the well water and the river water are hard, and the well water is slightly sulphurous and chalybeate. Water is found most abundantly at a depth of 30 to 50 feet near the base of the gravels of the river valley. Such water is liable to contamination, being unprotected by beds of clay or other impervious stratum. For this reason the water company have sunk to lower horizons, obtaining some water from near the bottom of the glacial drift after passing through a bed of blue bowlder clay, and some from the rock. Numerous private wells have been sunk in the city to the water bed near the base of the glacial drift, and these supply a limited quantity but excellent quality of water. The use of river water by the city is highly objectionable, because of the location of gas wells along the stream a few miles above the city, from which there is more or less leakage. (Information furnished by Mr. F. A. W. Davis, superintendent of Indianapolis Water Company.)

Knox, Indiana.—In the vicinity of Knox and throughout much of Stark County water is obtained in the surface sand, it being difficult to case it out and reach a lower water horizon. There is some uncertainty also in the supply from lower horizons. The use of such wells necessitates much care in the prevention of surface contamination.

Kokomo, Indiana.—The public water supply of Kokomo was obtained by drilling several small wells in the bottom of two large excavated wells. There are also wells drilled in the vicinity of the water-works station from which water is piped into the large open wells. The water, being from a pyritiferous limestone, contains sufficient iron sulphate formed by decomposition of the pyrites to be detectable, but not, as a rule, objectionable. Deep wells are discussed on another page.

Lafayette, Indiana.—The public supply for the city of Lafayette is from a bed of gravel underneath the Wabash River at a level about 40 feet below the bottom of the stream. Prof. H. A. Huston, State chemist of Indiana, reports that since this source of supply was substituted for the ordinary water of the river in 1892, there has been a decided improvement in the health of the city, which he attributes to the better quality of the water. Professor Huston has furnished the following analysis of this water:

	Parts in 100,000.
Chlorine	0.85
Nitrogen in ammonia salts	0.0005
Nitrogen in albuminoids	0.0018
Nitrogen in nitrites	None.
Nitrogen in nitrates	0.4610

	Parts in 100,000.
Phosphoric acid	None.
Sulphur trioxide	2.28
Silica	1.08
Iron and aluminium oxides	0.32
Calcium oxide	10.82
Magnesium oxide	4.42
Potash (K_2O)	0.82
Soda (Na_2O)	2.64

Hardness { Permanent, 6 degrees (Clark).
Temporary, 6 degrees (Clark).

Professor Huston states that the water is hard for boilers and a great soap consumer, but that from a sanitary standpoint no better has been found in the State. He considers the well water obtained on the slopes of the Wabash bluffs an unsafe supply.

An artesian well in this city, made some years since, obtains a flow of sulphurous water from a depth of 235 feet and a gas-well boring obtains a salt sulphur water at a lower depth, the boring being 1,000 feet. These are discussed on another page.

Logansport, Indiana.—The public water supply is mainly pumped from Eel River, but several springs in the bluff north of Eel River are collected in wells and supplied by the waterworks to the city for drinking. The water power from a race connected with Eel River is used in pumping, and has supplanted the use of an engine. The private wells in the city are found in gravel near the level of the Wabash and Eel rivers. In some cases they penetrate a bed of clay, but are usually entirely through loose sand and gravel and are thought to be liable to contamination. (Information given by W. B. Ray, city engineer.)

Marion, Indiana.—The city of Marion draws its public water supply from two sources—wells in the drift about 70 feet deep and wells in limestone about 240 feet deep. The water flows from both classes of wells, but the flow is not sufficiently rapid to furnish what is needed, hence a compressed-air lift is used. The water is very hard and is slightly chalybeate. An 8-inch well furnishes ordinarily about 4,000 barrels a day. (Information furnished by Louis Von Behren, mayor.)

Martinsville, Indiana.—There are three classes of wells in this city: (1) Wells 20 to 30 feet in depth, driven or excavated in the gravel of the White River Valley; (2) flowing wells 40 to 60 and occasionally 90 to 120 feet in depth, obtained in beds of gravel beneath glacial clay; (3) deep wells sunk for use at the sanitariums, 675 to 1,490 feet in depth, the majority being about 700 feet. The water is sulphurous and moderately saline, as well as hard. Analyses are given on another page, and also other statistics concerning the use of this water by the sanitariums.

The city water supply is obtained from one large open well 30 feet in diameter and 30 feet in depth, together with nine driven wells of similar depth. No grounds for suspecting its contamination are known, though the cover is apparently rather imperfect. (Information furnished by Henry Shereman, jr., postmaster, and by C. S. Cunningham, esq.)

Michigan City, Indiana.—The public water supply is obtained from several 6-inch driven wells, supplemented in seasons of drought by water from Trail Creek. Water from the drift is preferred to a sulphurous artesian-well water, which may be obtained by sinking wells into the underlying Niagara limestone. (Information furnished by A. W. Frehse, superintendent of waterworks.)

Mitchell, Indiana.—Wells are usually obtained in the vicinity of Mitchell at a depth of 30 to 50 feet, the greater part of which depth is through a decomposed limestone. A few wells have been sunk to a depth of 100 feet in order to obtain a greater supply. A gas-well boring was sunk to a depth of 1,200 feet and obtained a supply of salt water, which rises nearly to the level of the well mouth. This water is used for street sprinkling, but is thought to be too salt for domestic use or for sprinkling lawns.

New Albany, Indiana.—The city of New Albany obtains its waterworks supply from the Ohio River, but several public wells and a large number of private wells are obtained from the gravel of the terrace on which the city stands. Numerous analyses of the water from public wells have been made by J. F. Elsom, of New Albany. At the request of the mayor, Mr. T. W. Armstrong, Mr. Elsom furnished the following statement concerning the average of water from the city wells. In all cases the selections were made when the water in the wells was extremely low and suspicion of contamination strong.

	Parts in 100,000.
Total solids	80.02
Organic carbon	0.739
Organic nitrogen	0.093
Ammonia	0.740
Sewage contamination	32.850

Hardness: Temporary, 22.090. Permanent, 26.210.

Newcastle, Indiana.—The public water supply is from flowing wells sunk about 90 feet in the glacial deposits. A large supply of excellent water can be obtained in the drift of this vicinity at depths ranging from 20 to 250 feet or more. Analyses of the water from the waterworks wells are presented in the table of analyses on another page.

Plymouth, Indiana.—The public water supply for Plymouth is obtained from a series of flowing wells sunk in the glacial drift to a depth of 40 to 50 feet. The water is hard and chalybeate, and the supply is apparently inexhaustible. Wells of this class are found along Yellow River and other streams in Marshall County, and water rises to a corresponding level in extensive districts between streams.

Richmond, Indiana.—The public supply for the city of Richmond is obtained from spring water. An analysis made by Prof. D. W. Dennis shows the water to be free from nitrites and free ammonia and saline ammonia, and there is only a trace of albuminoid ammonia. A comparison with wells in the city leads Professor Dennis to the conclusion that more or less malaria exists where these wells are used, but none has been traced to the use of the water from the waterworks. The shallow wells in the city are considered less safe than the water from the springs or of Whitewater River, and their use should be discontinued wherever practicable. The hardness of the water varies slightly with the season. It averages about 27 parts of carbonate of lime in 100,000.

Rochester, Indiana.—The city of Rochester obtains its public supply from springs which are run into a well and filtered before the water is pumped into the tank. It is thought to be uncontaminated, although the works are located within the city limits. An artesian well at the public square obtains a supply of water at a depth of about 500 feet, which is sulphurous and chalybeate as well as hard. (Information furnished by William Jay Shields, postmaster.)

Rockville, Indiana.—The city of Rockville has thus far been unsuccessful in obtaining an adequate water supply for public use. Three prospective wells have been drilled to depths of about 200 feet each and a fourth to a depth of about 100 feet without finding an adequate supply. The completion of the waterworks is therefore suspended for the present. Private wells within the city range from 15 to 75 feet in depth in glacial drift, the depth varying greatly on adjoining blocks. There appears to be no well-defined water horizon within easy access. An unsuccessful gas-well boring was sunk some years ago to a depth of 2,300 feet. It obtained water, but the water failed to reach the surface, and no use was made of the boring. (Information furnished by Capt. John T. Campbell.)

South Bend, Indiana.—The public water supply for the city of South Bend is obtained from about thirty flowing wells driven to a depth of 100 to 125 feet in the glacial drift. A compact calcareous clay nearly free from pebbles and having a thickness of 20 to 40 feet rests upon the water-bearing gravel and prevents surface contamination. The head was originally about 15 feet above the surface in wells located

on the low ground along the river bottom. The greater part of the city stands upon a terrace 20 to 30 feet above this bottom, and consequently above the level to which water will rise. The following analysis was made by Prof. Albert Prescott, of the University of Michigan:

	Parts in 100,000.
Free ammonia	0.010
Albuminoid ammonia	0.008
Nitrates	None.
Nitrogen in nitrites	0.007
Chlorine of chlorides	0.600

Hardness (Clark's scale), 13 degrees.

Professor Prescott states that in the sanitary relations the water is better than the average of good city water supplies. (Information furnished by William M. Whitten, city engineer.)

Sullivan, Indiana.—The private wells in this village usually obtain abundant supply in glacial drift at 25 to 35 feet. In the surrounding country wells are often sunk to a depth of 200 to 300 feet, obtaining a supply of fresh water in the sandstone. A gas-well boring made by the city reached a depth of about 1,000 feet and struck a strong flow of salt water, which rises within 15 feet of the surface. This water is being used for street sprinkling, but is so salt as to leave a white incrustation when evaporated. The city waterworks, recently constructed, obtain a supply from Busseron Creek. The water is filtered before it is pumped to the standpipe.

Terre Haute, Indiana.—The city of Terre Haute is supplied chiefly by water pumped from the Wabash River, there being but few private wells. The danger of contamination of the water of the wells is so great that frequent analyses are made, and where contamination is known to exist further use is prohibited by the city authorities. The following table of analyses, made by Prof. W. A. Noyes, of the Rose Polytechnic Institute, in 1891, includes water from several wells, in addition to that from the city hydrants, and illustrates the nature of the supplies:

[Parts in 100,000.]

	Hydrant water.	Deep well at Terre Haute House.	Well at 610 Eagle street.	Well at Fourteenth and Poplar streets.	Well at Thirteenth street and College avenue.	Well at Twelfth and Wabash streets.	Well in front of 519 North Fourth street.	Well at Third street and Washington avenue.
Total solids	280	404	730	375	373	421	644	332
Chlorine	12.9	11.7	41.7	7.4	10.6	12.4	20.8	4.6
Nitrogen in nitrates	1.4	9.6	22.6	9.1	11.1	10.6	16.0	8.2
Nitrogen in nitrites	None.	None.	0.05	0.002	0.001	0.002	0.002	None.
Free ammonia	None.	None.	0.10	None.	0.002	None.	0.004	None.
Albuminoid ammonia	0.08	0.003	0.12	0.004	0.004	0.008	0.044	0.020
Oxygen consumed by organic matter	1.25	0.24	0.72	0.28	0.24	0.26	0.44	0.24

"With the exception of the wells at 610 Eagle street and in front of 519 North Fourth street, th contamination is less than in the well waters examined the previous year (1890). Whether this is because most of the wells are located in the less thickly populated parts of the city, or because, on account of the small amount of rain, the surface drainage forms a smaller part of the water in the wells, can only be determined by new analyses of some of the wells examined last year. In any

case, however, the analyses show that a part of the water in each of these wells has at some time in its history been contaminated with organic matter."—W. A. Noyes.

Union City, Indiana.—The supply for the Union City waterworks is obtained from two wells, each 30 feet in diameter and 32 feet deep. The water stands at an average depth of about 25 feet in each well, or within 7 feet of the surface. The wells are dug through a tough, bluish clay to a dark sand, which, when reached, supplies water in such quantities as to preclude further progress. The water is thought to be very pure and healthful. In twenty-three years no case of typhoid fever or diphtheria has originated in a family using it exclusively, nor has deleterious matter been detected in it. (Information furnished by William Commons, M. D., health officer.)

Valparaiso, Indiana.—The public water supply for this city is obtained from Flint Lake, situated about 3 miles north of the city. As there are no streams leading into this lake, its water is supplied from direct rainfall and from percolation through surrounding gravel beds. In dry seasons it shrinks to such an extent that the supply is scarcely sufficient to meet the demands of the city, and plans are under way for connecting the waterworks system with other small lakes in that vicinity. Private wells and cisterns are used extensively. The wells range in depth from 15 feet to about 200, and obtain their supply from gravel beds in the glacial drift. (Information furnished by J. C. B. Suman, mayor.)

Wabash, Indiana.—The public water supply for the city of Wabash is obtained from flowing wells sunk in the valley of Treaty Creek, about a half mile south from the Wabash River bluff. The wells range in depth from 42 to 55 feet, and are 6 inches in diameter. Only a small part of the water goes into the reservoir, and yet an adequate amount is obtained for the use of the city.

Many wells have been drilled into limestone within the city, but the present waterworks supply has largely supplanted them because of its superior quality. A deep artesian well made many years ago has also nearly gone out of use. (Information furnished by James E. McHenry, mayor.)

Warsaw, Indiana.—The public supply is obtained from sixteen 2-inch wells 138 feet deep, one 8-inch well 141 feet deep, and one 6-inch well 140 feet deep. The head in these wells is sufficient to cause them to flow 1 to 2 feet above the surface. In addition to the wells, water is pumped from one of the lakes situated on the borders of the city.

Whiting, Indiana.—Part of the town is supplied from Lake Michigan by the private pumps of the Standard Oil Company's plant, but a part of the town still use well water obtained in the surface sand.

OHIO CITIES AND TOWNS.

Akron, Ohio.—Several wells driven in gravel to depths ranging from 60 to 125 feet furnish the public water supply. This is supplemented by pumping from a small lake. The wells each have an average yield of about 100,000 gallons per day. The average daily consumption is about 3,000,000 gallons. A portion of the city is underlain at slight depth by sandstone in which water is readily obtained for many private wells. A few families on the west side are supplied from springs.

Ashland, Ohio.—Water supply from wells at pumping station is abundant at 30 feet or less, but one of the best wells is 90 feet. Average daily consumption about 50,000 gallons. Daily capacity of a well averages about 50 barrels, but some wells are much stronger. Analysis of water given in tables on later page.

Ashtabula, Ohio.—The public supply is from a series of tubes and infiltration wells, 6 to 14 feet deep, in gravel on the shore of Lake Erie.

Athens, Ohio.—Waterworks supply is from a large well, 23 feet deep and 30 feet in diameter, situated just above the city in the Hocking River bottom, at a distance of

1,700 feet from the river. Water enters through coarse gravel and is probably fed by the river, its bottom being below river level. In dry seasons 750,000 gallons per day is pumped without lowering the well, and occasionally twice that amount. Average daily consumption nearly 200,000 gallons. (Information furnished by William S. Wilson, mayor.)

Attica, Ohio.—The public supply is from a large well, 28 by 25 feet, fed by tile leading through a gravel bed 6 to 11 feet from surface of ground. This well will furnish 750 gallons per minute in ordinary seasons, or far more than the demands of the village. The private wells obtain water at about 20 feet. (Information furnished by A. F. Lepper, postmaster.)

Bellaire, Ohio.—Public supply pumped from Ohio River is considered unsafe because of the situation just below the city of Wheeling, but is used by a large part of the population. Private wells obtain supply at level of river, except in a few instances where rock is penetrated. Rock water is often slightly saline. A 6-inch well in the river alluvium will ordinarily supply 50 gallons per minute. Such wells are considered safer than the river water. (Information furnished by James Kenney, jr.)

Bellefontaine, Ohio.—The public supply is from two flowing wells, 164 feet in depth, located on ground about 13 feet lower than the Cleveland, Cincinnati, Chicago and St. Louis Railway station. The water is pumped to a reservoir. The combined capacity by pumping is about 1,000,000 gallons per day. Average daily consumption about 750,000 gallons. The analysis shows it to be an alum water, there being nearly 3 grains per gallon of sulphate of alumina. (Information furnished by W. T. Haviland, postmaster.)

Bellevue, Ohio.—Several wells in the city appear to have an inexhaustible supply of water from limestone at depths of 40 to 75 feet, but the majority have a limited capacity. The strong wells are supposed by the residents to be located in a "subterranean stream." The public supply is impounded water pumped to standpipe.

Berea, Ohio.—The wells are partly in drift at depths of 15 to 20 feet, partly in shale at similar depths, and partly in Berea grit at 60 to 75 feet. There is but little rise of water in the wells. Strength of wells varies greatly. (Information by Dr. D. T. Gould.)

Bucyrus, Ohio.—Public water supply partly from a large well, 50 by 20 feet, and partly from Sandusky River. Private wells, 10 to 40 feet in depth, are mainly through bowlder clay and obtain water in glacial gravel. (Information furnished by Charles Donnenwirth, mayor.) The Waterworks Manual reports average daily consumption 550,000 gallons.

Canton, Ohio.—The public water supply is about equally divided between Nimishillen Creek and 36 flowing wells, there being pumped from each source about 1,500,000 gallons daily. The flowing wells are 275 to 385 feet in depth and obtain supply from sandstone. Such wells overflow only on low ground along the creek. (Information by A. M. True, superintendent of waterworks.)

Celina, Ohio.—Very large supplies of fresh water may be obtained from the drift gravels at 50 or 60 feet or less and from limestone at about 250 feet. The average capacity of a drilled well is estimated to be 1,500 barrels per day. The drift near Celina in places is fully 300 feet, but ordinarily is scarcely 100 feet in depth.

Cincinnati, Ohio, and suburbs.—The city of Cincinnati is supplied with water pumped from the Ohio River to reservoirs for both low service and high service. The suburban towns of Madisonville, Linwood, Norwood, Carthage, St. Bernard, Bond Hill, Lockland, Hartwell, Reading, Wyoming, and Glendale are all located in an abandoned valley connecting the Ohio with the Great Miami. This valley is filled with a fine sand, which yields an abundance of good water for the use of these towns. The wells are 100 to 235 feet in depth, the deepest being at Norwood. Dr. John B. Porter, of Glendale, estimates that these suburban towns have an average daily summer consumption by public and private wells of not less than 4,000,000 gallons and occasionally pump 10,000,000 gallons. The wells at Glendale pumping station

penetrate 97 feet of clayey drift before entering the water-bearing sand and are sunk 78 feet into the sand. The water there shows a trace of free ammonia, but no albuminoids. It is hard, fully 75 per cent of its mineral matter being carbonate of lime. Dr. Charles L. Metz, of Madisonville, reports that the three wells at the waterworks of that village are on the lowest ground in that vicinity (along Duck Creek), and are 140, 145, and 150 feet in depth. At 16 feet sand was entered which continues to bottom. Water is hard and incrusts standpipe. A sanitary analysis shows the following:

	Parts in 100,000.
Free ammonia	0.0062
Albuminoid ammonia	0.0050
Nitrates and nitrites	0.0443
Chlorine	0.45
Volatile organic solids	4.50
Inorganic solids	30.75
Total solids	35.25

Cleveland, Ohio.—The public supply is from Lake Erie, the water being taken at a crib 1 mile from the shore. Very few private wells are in use. Two reservoirs are constructed, a low service 170 and a high service 315 feet above the lake. Miles of pipe connected with low service, 390; with high service, 43. Total, 433 miles. Manual of American Waterworks reports 462 miles in June, 1896. Average daily consumption of water nearly 40,000,000 gallons. (Information by Mr. Warren Upham.)

Clyde, Ohio.—In the vicinity of this village are flowing wells 50 to 75 feet in depth. The rate ranges from 10 barrels to fully 500 barrels per day. The public supply is from limestone, and water is sulphurous as well as hard. (Information by D. Beamer.)

Columbus, Ohio.—The city of Columbus embraces within its limits three valleys and tracts of upland in which water horizons are variable. In places drift deposits exceed 100 feet; in places the drift is thin. Some water is obtained at 10 to 15 feet, but a better supply is found at 30 feet or more, the depth to strong water veins varying greatly within narrow limits. Some shallow wells may be subject to contamination, but clay strata usually protect such wells. The public supply is from Scioto River and impounded water at main station and from wells at East Side station. Average daily consumption, 14,000,000 gallons. Few wells, either for public or private supply, enter rock. The water is hard and contains a small amount of iron and sometimes is sulphurous. (Information by Dr. Edward Orton, State geologist.)

Conneaut, Ohio.—Public supply chiefly from eight 5-inch wells on the shore of Lake Erie, with a daily combined capacity of 1,000,000 gallons. Dug wells for private use are being supplanted by driven wells.

Coshocton, Ohio.—The public supply is from eighteen 6-inch wells 32 feet in depth, which reach about the level of the Tuscarawas River and obtain the supply from gravel.

Dayton, Ohio.—The public water supply is from about eighty 8-inch wells driven to a depth of 50 to 60 feet through alluvial and glacial sand and clays in Mad River Valley to a bed of gravel. The daily consumption in summer averages about 6,500,000 gallons, and for the year about 4,000,000 gallons. Length of mains about 100 miles. Chemical analyses are given in the tables on another page, and show the water to be rather hard. A bacteriological examination made by Dr. S. E. Allen, of Miami Medical College, showed no pathogenic germs, the varieties isolated being the perfectly harmless forms which exist in all water not artificially sterilized. The number of germs is exceedingly low, being but 48 per cubic centimeter.

Defiance, Ohio.—The public water supply is pumped mainly from Maumee River. Private wells are from two horizons, the shallow ones being but 10 to 15 feet and the deeper ones 40 to 50 feet in depth. Some of the former having shown evidence of

contamination, this class is regarded with suspicion. An analysis of a deep salt-water well appears on another page. The shallow wells have fresh water.

Delaware, Ohio.—The city water supply is from large wells located about 3 miles north of the city and excavated in gravel to a depth of 30 feet. In the city there are a number of springs of sulphur water. There is also a deep well, bored for natural gas, which furnishes water for a bath house under the direction of Dr. S. W. Fowler. Analyses of water from two of the springs are presented in the tables on another page. They show the samples to be a highly saline sulphureted water. The sulphureted hydrogen in Odovene spring, amounting to nearly 3 cubic inches per gallon, is entirely free, no sulphides occurring in the water except a minute trace of sulphide of iron in suspension. (Information furnished by C. W. Wiles, superintendent of waterworks, and by Dr. S. W. Fowler.)

Dennison, Ohio.—Dennison and Uhrichsville are practically one town, standing in the valley at the junction of Stillwater and Tuscarawas rivers. In Dennison the wells are 12 to 20 feet in depth, obtaining water from sand beneath yellow clay. In Uhrichsville the wells are usually deeper. Very few wells have been sunk since the waterworks were put in operation in 1888. The waterworks pumping station is on Big Stillwater River, above the towns, and the reservoir stands on a hill 265 feet above the level of the valley bottom. (Information given by E. Eckfeld.)

Eaton, Ohio.—The waterworks are located in a creek bottom one-half mile northwest of the corporation line. Ten 6-inch wells 75 to 85 feet deep are connected with the pumps. These furnish only 100,000 gallons per day, which is insufficient for the demands of the city. Recourse is had to spring water issuing at the foot of the bluff, which supplies about 100,000 gallons per day. The spring water has a temperature of 49°, while the well water stands at 56°. An analysis of the combined water is presented in the table of analyses. (Information furnished by W. C. Dove, superintendent of waterworks.)

Elyria, Ohio.—The public supply is pumped from Black River and is not satisfactory on account of the large amount of sediment. Private wells are of two classes: (1) Shallow wells in the drift, 10 to 30 feet in depth; (2) wells in sandstone, 60 to 90 feet in depth. The water in the former is not above suspicion, but from the latter source it is excellent, and the supply is abundant for private purposes. Whether a public supply could be obtained from this source has not been determined. (Information furnished by M. H. Levagood, mayor.)

Findlay, Ohio.—The public supply is pumped from Blanchard River, which runs through the city. The glacial drift is seldom of sufficient thickness to afford a supply for private wells, but water is often found in the underlying limestone at a depth of but 12 to 15 feet. In some cases the water is sulphurous, but is usually of pleasant taste. In some localities much discomfort is experienced on account of the saturation with oil, which escapes into the drift gravel from the oil wells.

Franklin, Ohio.—The public supply is from six 6-inch wells driven into the glacial drift of the Great Miami Valley. Prior to the introduction of this public supply, in 1887, shallow wells 20 to 30 feet deep were in use, which, it was thought, led to the prevalence of typhoid fever, but since the utilization of the deeper wells the town has experienced no run of typhoid fever. The following sanitary analysis of the waterworks supply was made by Prof. O. R. Stuntz, in April, 1887:

	Parts in 100,000.
Total residue	45.94
Organic and volatile	17.92
Inorganic and nonvolatile	28.02
Free ammonia	0.0016
Albuminoid ammonia	0.0021
Chlorine	1.04

Hardness: Temporary, 8.51. Permanent, 14.38. Total, 22.89.

Fremont, Ohio.—The public water supply is mainly from the Sandusky River. Private wells are obtained in the drift at convenient depths, but there is suspicion of their contamination in many instances. An excellent quality of water may be obtained at a depth of 40 to 60 feet in the limestone. It is estimated that drilled wells of this class yield, in some cases, nearly 1,000 barrels per day. (Information furnished by Charles F. Reiff, superintendent of waterworks.)

Gallipolis, Ohio.—The public water supply is from wells sunk in the bed of the Ohio River. Four wells, 6 feet deep and 4 feet in diameter, extend down about 5 feet below extreme low water in a bar at the head of Gallipolis Island. The wells are cemented at top, so that when the river overflows them no water enters except that which comes up from beneath. The water is thus comparatively clear at times when the river carries much sediment. Water is pumped to a reservoir 314 feet above low water in the Ohio. The average daily consumption in summer is 300,000 gallons.

Greenville, Ohio.—The public supply is from nine 6-inch wells 52 to 62 feet in depth, which obtain their supply from glacial gravel at the base of the drift, there being limestone at the bottom of each of the wells. The average capacity of each well is about 5,000 barrels per day. A sanitary analysis made by Prof. C. R. Stuntz, of Cincinnati, in December, 1892, reports a large amount of free ammonia, as well as much organic matter. The organic matter is largely composed of peat, and it is recommended that the water should be filtered. One analysis is from a sample of the waterworks water, and the other from Greenville Creek, and the results are as follows:

	Parts in 100,000 by weight.	
	Well water.	Creek water.
Total solids	54.02	40.46
Organic and volatile solids	19.56	15.46
Inorganic	34.46	25.00
Free ammonia	0.1012	0.0034
Albuminoid ammonia	0.0034	0.072
Chlorine	0.45	0.19
Temporary hardness (grains per United States gallon)	16.61	5.39
Permanent hardness (grains per United States gallon)	12.76	11.95

(Information furnished by John P. Lucas, superintendent of waterworks.)

Hamilton, Ohio.—The city of Hamilton is supplied by a series of filter wells obtained at about the level of the Miami River in glacial gravel, the average depth being 45 feet. The capacity of the wells is practically inexhaustible, but they are pumped at a rate of about 3 barrels each per minute.

Hillsboro, Ohio.—The public supply is from gravel beds reached by twelve driven wells in the valley of Clear Creek, about 2½ miles north of the village. The supply is rather scanty, but probably sufficient if carefully husbanded. The town has a hilly situation, the Niagara limestone cropping out in places on the slope. The irregular surface is filled in by drift deposits from which some well water may be obtained. The source of supply, however, is looked upon with suspicion, as it may easily become contaminated. Wells in the rock range in depth from 10 to 50 feet. (Information furnished by Judge H. M. Huggins.)

Hudson, Ohio.—Hon. M. C. Read has published a paper upon the water supply of

Hudson and vicinity, in which it is shown that many shallow wells are obtained at the junction of the yellow and blue till at depths of 10 to 15 feet or less. This source of supply he considers dangerous, for the reason that the yellow clay in seasons of drought opens a series of fissures which readily admit the washings of the surface in showers following such droughts. As in underdraining clay lands the fissures will be opened more rapidly near the drains, on account of the earlier desiccation along them, so they will open up more rapidly for the same cause around the wells, and these will be put in complete communication with the network of openings reaching to the surface. In examining such wells Mr. Read has found centipedes, sow bugs, and earthworms by hundreds brought up in the first drawings of water after copious summer showers. They had sought moisture in the fissures of the clay, and the fact that they were uniformly carried in great numbers into the well when a dashing rain succeeded a long-continued drought shows how directly these fissures connected with the well. In view of these studies made by Mr. Read it can not be too strongly urged that in districts such as that around Hudson, where a drought may open fissures in the clay to the depth of the water-bearing stratum, special pains should be taken to guard against the use of such wells. Over much of northern and northwestern Ohio, where the surface is largely a compact clay, the dangers from this source are as great as at the village of Hudson, where the observations were made. Mr. Read has devised a double cistern, one apartment receiving the water and allowing it to filter through charcoal and gravel into the other apartment, from which the water is pumped. By occasional renewal of the filtering material and washing of the cistern he has been able at slight expense to obtain a supply of water as clear and sweet as the best spring water. In localities where pure well water can not be readily obtained this simple device may be easily employed for obtaining a pure quality of rain water.

Ironton, Ohio.—The city of Ironton obtains its supply by direct pumping from the Ohio River, and no private wells are in use. Because of the sediment carried by the river at certain seasons of the year many large cisterns have been constructed which are filled from the waterworks before the spring rise, while the water is clear. (Information furnished by John M. Corns, mayor.)

Jackson, Ohio.—The city of Jackson is very unfortunately situated for obtaining an adequate supply for waterworks. The nearest available supply appears to be Raccoon Creek, several miles distant, and the water of this stream is somewhat objectionable. The wells within the city usually obtain water at 18 to 25 feet, but a good well is estimated to have an average capacity of but 3 or 4 barrels per day. (Information furnished by Andrew Leach, mayor.)

Kenton, Ohio.—This city is supplied from a large well about 25 feet in diameter and 100 feet deep. With the exception of about 20 feet of drift, it was blasted from solid rock. The water stands at about the level of the top of the rock, and can be lowered only by excessive pumping. (Information furnished by Elmer G. Derr.)

Lancaster, Ohio.—The public supply is from springs, a sanitary analysis of which was furnished by Professor Welsh:

	Parts in 100,000.
Free ammonia	0.003
Albuminoid ammonia	0.007
Nitrous acid	0.001
Nitric acid	0.108
Chlorine	1.840
Total solids	44.500

Lima, Ohio.—The public supply is from several wells drilled to a depth of 140 to 148 feet in limestone. The best well is pumping 800,000 gallons daily. Average daily consumption exceeds 1,000,000 gallons. Private wells furnish only a small portion of the domestic supply, for it is usually necessary to drill into the rock, and thus incur much expense, to obtain a good supply of water. (Information furnished by H. B. Hackedon, superintendent of waterworks.)

London, Ohio.—The city of London obtains a large supply of excellent water from flowing wells at about 150 feet in the glacial drift. There are three 6-inch and two 8-inch wells, with a united capacity of about 800,000 gallons per day. Many strong wells are obtained at shallower depths, but the head is not so great as in the deeper ones. (Information furnished by J. M. Boyer.)

Lynchburg, Ohio.—Through the village of Lynchburg there is a gravelly belt, estimated to have an average width of about one-fifth mile, in which an abundance of water may be obtained at depths of 15 to 20 feet. On either side of this belt limestone is struck at slight depth and only weak wells are obtained. The waterworks obtain a supply from this gravel belt. Its well is 16 by 20 feet, and reaches rock. (Information furnished by Manual of American Waterworks and by Daniel Murphy, county surveyor.)

Mansfield, Ohio.—The public supply is from a series of flowing wells 100 to 140 feet in depth, located in a valley adjoining the city, and which discharge water into a reservoir. It is thought that an adequate supply may be obtained by increasing the number of these wells. It is proposed to sink a sufficient number to afford 2,000,000 gallons per day. (Information furnished by R. B. McCrary, mayor.)

Marietta, Ohio.—Although the waterworks supply is obtained from the Ohio River, many wells, both public and private, are in use which obtain water in gravel at depths of 30 to 90 feet. There is a suspicion of considerable contamination, and the use of such wells is decreasing. (Information furnished by J. B. West, superintendent of waterworks.)

Marion, Ohio.—The public water supply is obtained from a gravel pit in Little Scioto Valley, about 2 miles west of the city, at a level about 65 feet below the general level of the city. About 2 acres of ground were excavated to a sufficient depth to form a pool. Test borings indicate that the gravel extends 50 or 60 feet below this level and is filled with an excellent quality of water. The water is used satisfactorily by the railways for locomotives, there being less than 14 grains of carbonate of lime per gallon. (Information furnished by H. C. Stillwell, superintendent of waterworks.)

Massillon, Ohio.—The city of Massillon is chiefly supplied from a series of flowing wells drilled into the sandstone, some of which are 100 to 150 feet in depth. Water for domestic use is also obtained from Sippo Lake. The wells have an average capacity of about 500,000 gallons each per day. The water is remarkably hard, considering its derivation from a sandstone rock, there being, as shown by the analysis in the tables, 12.65 grains of carbonate of lime per gallon. (Information furnished by A. W. Inman, superintendent of waterworks.)

Mechanicsburg, Ohio.—The village of Mechanicsburg depended entirely upon open wells for domestic supply until 1892, when wells were driven to a bed of gravel below the bowlder clay. The greater part of the supply is still obtained from open wells, and an epidemic of typhus which prevailed in 1894 is thought to have resulted from the use of such wells. (Information furnished by T. E. Burnham.)

Mount Vernon, Ohio.—The waterworks supply is obtained from twenty-four flowing wells, 2 to 6 inches in diameter, driven to depths of 63 to 97 feet in the glacial drift. A 6-inch well is estimated to have an average capacity of about 100 gallons per minute, or nearly 150,000 gallons per day. The water is chalybeate as well as hard. A well drilled into the rock at Mount Vernon obtained a flow of brackish water unsuitable for use by the waterworks. The following sanitary analysis of water from the wells in the drift was made by Professor Lord, of the State University:

Free ammonia, 0.017 parts in 100,000.
Albuminoid ammonia, traces.
Chlorine, 0.35 grains per United States gallon.
Total solids, 16.0 grains per United States gallon.
Combustibles, 2.0 grains per United States gallon.
Hardness, 11.5.

Napoleon, Ohio.—In the portion of the town lying between the Maumee River and Canal water is obtained at a depth of 15 to 30 feet. In the remainder of the town wells are usually obtained in the rock at a depth of 110 to 130 feet. Many of the wells in rock have a sulphurous water which is not pleasant for drinking. For this reason filtered cistern water is used by a large per cent of the people. The waterworks and electric lighting are in one plant, run by the same machinery and a single set of employees. The cost of the plant was $60,000, but how much of this should be charged to water supply is not known. (Information furnished by Charles Evens.)

Nelsonville, Ohio.—The public water supply is obtained from a large well sunk to a depth of 25 feet in the gravel of the Hocking River Valley at a distance of 200 yards from the stream. There is very free movement of water through this gravel, and the supply is inexhaustible. Private wells are largely abandoned since the construction of the waterworks.

Newark, Ohio.—The public water supply is from large wells excavated at the bank of the north fork of Licking River, in the northern part of the city. The water is considered very pure and wholesome. It is rather hard, there being about 20 grains of carbonate of lime per gallon. (Information furnished by William A. Veach, receiver for company.)

New Lisbon, Ohio.—The public water supply is from two sources, about 25 per cent being pumped from wells drilled into the sandstone rock and the remainder stream water. The water from the stream is carried by gravitation into a large cistern into which also the well water is pumped. The entire supply is then forced to a reservoir on a hill standing about 200 feet above the pumping station. One pump is arranged to force water direct from the pumping station through the mains. The wells have an average capacity of about 40,000 gallons each per day. (Information furnished by I. M. Dickenson, mayor.)

New Philadelphia, Ohio.—The public water supply is from a series of wells in the Tuscarawas River bottom, driven about to the level of the river bed. A few wells have been sunk to a depth of 25 or 30 feet below the river bed, and it is thought that the supply from this source is not so hard as that found at the level of low-water mark. The water is pumped to a reservoir on a hill adjacent to the town. Private wells are obtained at about the level of the river and vary from 20 up to 50 feet, according to the elevation of the surface. (Information furnished by Joseph Welty.)

New Straitsville, Ohio.—This village is built upon the slope of a hill about 150 feet in height, and the wells are obtained from several different horizons. In some cases the water is strongly impregnated with iron and sulphur, especially that found below "Coal No. VI." Surface water is collected in reservoirs for mining industries and iron furnaces, and in cisterns for fire purposes.

Niles, Ohio.—This city obtains its public water supply from nine wells sunk to a depth of 50 feet in glacial deposits. The combined capacity is about 500,000 gallons per day.

Oberlin, Ohio.—The public water supply is pumped from the east branch of Vermilion River, at Kipton, six miles distant. An analysis of the river water made at the end of a dry season, September, 1886, gave the following results:

Total solids, 35.35 grains per gallon.
Hardness, 32.66 degrees.
Hardness after a rain, 12 degrees.
Free ammonia, 0.0094 parts in 1,000,000.
Albuminoid ammonia, 0.02 parts in 1,000,000.

Many private wells are in use which obtain water from sandy layers between the yellow and blue till, at depths of 8 to 12 feet, and in the gravel beds at lower depths in the drift. Near the west part of the town the Berea grit is within 3 to 6 feet of the surface, and wells are there drilled some distance into the rock. The well water has occasionally been found to show contamination in the series of

analyses made by Professor Jewett. In one case contamination by a cesspool was certain. In thirteen analyses of water suspected to be bad, made by Professor Jewett, the amount of free ammonia was found to vary from 0.001 part in 100,000 to 0.033 parts. The albuminoid ammonia ranged from 0.005 to 0.027 parts in 100,000. The amount of chlorine in grains per gallon ranged from 0.80 to 16.10, the latter being the amount in a well known to be contaminated by a cesspool. The average amount of chlorine in the thirteen analyses is 6.43 grains per gallon. As all these waters were selected for their known badness they can scarcely be considered representative, but they serve to indicate that there is danger arising from the use of the shallow wells. (Information furnished by Prof. A. A. Wright.)

Ottawa, Ohio.—No public water supply is yet introduced, but the city has a system of fire cisterns supplied from Blanchard River. There are also a few "town wells" which contain water from limestone at a depth of about 130 feet. The private wells are often obtained at depths of 10 to 35 feet, from gravel beds in the glacial drift. Quite a number of private wells are drilled into the rock, which is entered at about 70 feet from the surface. (Information furnished by T. J. Sweeney, mayor.)

Plain City, Ohio.—The public water supply is obtained from two artesian wells 500 feet in depth, which yield an unlimited amount of slightly sulphurous water, not unpleasant for drinking. This water is rapidly displacing the use of private wells, which were obtained at depths of 7 to 13 feet and are liable to surface contamination. (Information furnished by G. M. Russell, postmaster.)

Piqua, Ohio.—The public water supply is obtained through a somewhat expensive canal and basin system, supplied by Miami River, the cost of the system of canals and basins being $260,000. The canal is 6 miles in length, and the basins are of different sizes, one basin containing 40 acres, another 11, and another 3, and there are smaller ones. The quality of water is thought to be excellent. Private wells are obtained at depths of 10 to 24 feet, in beds of gravel. In some cases these wells are thought to be liable to contamination. An artesian well boring demonstrates that water will rise to about the level of the Miami Canal, but the head is scarcely sufficient to cause a flow at the general level of the city. (Information furnished by James Ward Keyt, mayor.)

Pomeroy, Ohio.—This city has no public water supply, principally because of the great indebtedness. A few wells, 60 to 65 feet in depth, are in use, but the greater part of the water supply is from cisterns filled from roofs of buildings. (Information furnished by E. R. Davenport, city engineer.)

Portsmouth, Ohio.—The public water supply of the city is obtained by direct pumping from the Ohio River. Very few private wells are in use, it being necessary to sink usually to a depth of 60 to 100 feet to obtain a supply.

Ravenna, Ohio.—The greater portion of the public water supply is pumped from a lake having an area of about 30 acres. This being inadequate, a system of wells have been sunk on the margin of the lake, which obtain an excellent quality of water, at a depth of about 150 feet in a bed of gravel at the base of the glacial drift. (Information furnished by D. C. Coolman, postmaster.)

Ripley, Ohio.—A system of waterworks was put in in 1896, which will obtain its supply from the Ohio River. The water is first pumped to two settling basins and from these to a reservoir on the bluff, about 300 feet above the river. Several private wells in Ripley reach depths of 85 to 90 feet without entering rock. An artesian well, made near the base of the bluff, obtains a salt water containing a considerable amount of lithium carbonate. The analysis is given in the tables. (Information furnished by Dr. W. A. Dixon.)

St. Marys, Ohio.—The public water supply is from four 8-inch wells about 280 feet in depth, sunk into the limestone, and which have a combined average daily capacity of 2,000,000 gallons. The water will rise to a height of 12 feet above the surface. It is very hard and has a small amount of sulphur and iron, but is of excellent quality. Wells of this class may be obtained over an area of several square miles in the vicinity of St. Marys, and many have been made by the farmers. The water

supply from the drift is of good quality and usually adequate for private wells. (Information furnished by O. E. Dunan.)

Sandusky, Ohio.—The public supply is pumped from Sandusky Bay. A private company has springs located about 6 miles west of the city, which furnish a small amount of excellent water. The use of private wells is almost discontinued. (Information furnished by Charles Judson, C. E., superintendent of waterworks.)

Sidney, Ohio.—The public water supply is pumped mainly from Great Miami River, and is of excellent quality. There are many private wells which also furnish a good quality of water. The open wells have a depth of 12 to 30 feet, and drilled wells a depth of 100 to 200 feet. (Information furnished by H. S. Ailes, mayor.)

Springfield, Ohio.—The public water supply is obtained from wells sunk into glacial gravel. There are also many private wells. The depth of wells in the higher part of the town is about 40 feet, but in the lower part is 15 to 20 feet. Usually water is obtained without entering rock, but in parts of the city the rock stands within 5 feet of the surface and wells there must be drilled. An analysis of the city water is given in the tables. (Information furnished by W. H. Linn, city engineer.)

Steubenville, Ohio.—A waterworks plant was put in at this city in 1836 and enlarged in 1865 on the old site. An entire new plant was built in 1894. Two reservoirs are constructed at different elevations. The higher one has a line of pipes connected with it which are used for fire; the lower one is used for domestic purposes. It is probably one of the most complete systems in the State. There is a pumping capacity of 6,000,000 gallons, a reservoir capacity of 7,000,000 gallons, and a daily consumption of about 2,500,000 gallons. (Information furnished by David McGowan.)

Tiffin, Ohio.—The public water supply is obtained partly from the Sandusky River, but recently seven 10-inch wells have been sunk into the rock, which furnish a combined average yield of about 800,000 gallons per day. Several factories and many private parties have wells sunk into the rock to depths of 70 to 90 feet. (Information furnished by Mr. M. Scannell, manager Tiffin waterworks.)

Toledo, Ohio.—The public water supply is pumped from the Maumee River. For some time after the construction of the waterworks a prejudice against using what was called hydrant water was felt, but it is now rapidly taking the place of all other water supplies, and nearly 50 miles of additional pipe has been laid since 1892, making 128 miles in all. The private wells were largely of shallow depth and as the sewerage system was developed their supply was drained, thus making it necessary either to sink deeper wells or use the hydrant water. The quality of the public water supply is considered to be such that no danger is attached to its use. (Information furnished by T. R. Cook, superintendent of waterworks.)

Troy, Ohio.—The public water supply is obtained from two open and five driven wells located in the Miami Valley just above the city. The open wells are 30 feet in depth and the driven wells 40 to 50 feet. The average combined capacity is estimated to be about 2,000,000 gallons per day. The water is of excellent quality, the only objectionable feature being its hardness. (Information furnished by A. T. Beedle, superintendent of waterworks.)

Urbana, Ohio.—The public water supply is from an open well 21 feet in depth and 20 feet in diameter, excavated in glacial gravel, and from eight 6-inch driven wells. They are estimated to yield 1,000,000 gallons or more per day. There are several manufactories that use outside supplies. The Artificial Ice Company have three wells 28 feet in depth, which supply about 450,000 gallons per day. The Urbana Strawboard Works have two wells 12 feet in depth and 6 feet in diameter, which supply about 500,000 gallons per day. The Ohio Strawboard Works have wells which supply their daily consumption of about 1,000,000 gallons. Impounded water from springs and brooks in the east part of the city supply the railway locomotives. There are many other wells for domestic and manufacturing purposes whose yield is not estimated.

The city is, therefore, richly supplied with water at shallow depths. A gas-well boring obtains a supply of water from a depth of 275 feet in a limestone formation. The capacity is estimated at 100,000 to 150,000 gallons per day. It has a head 33 feet above the level of the Pan Handle railway station, or about 1,060 feet above tide. (Information furnished by Dr. Thomas F. Moses.)

Van Wert, Ohio.—The city water supply is from wells sunk into the limestone to depths of 125 to 175 feet. The head is within 10 feet of the surface, but a pump of 1,500,000 gallons daily capacity has lowered six 6-inch wells 26 feet, continuous pumping ten hours. An analysis of water from these wells is presented in the tables. There are many private wells still in use which obtain water at about 20 feet, in beds of gravel beneath clay. (Information furnished by James F. Higgins, mayor.)

Wapakoneta, Ohio.—The public water supply is derived from nine 6-inch wells, varying in depth from 35 to 143 feet. The water from all the wells rises to the surface of the ground. The average capacity of each well is about 200 gallons per minute. The deeper wells reach the bottom of the drift, but do not penetrate the limestone. The following sanitary analysis, made by the State board of health, is from a sample taken from a well 45 feet in depth:

	Parts 100,000.
Oxygen required	0.10
Free ammonia	0.041
Albuminoid ammonia	0.003
Organic ammonia	0.005
Nitrous acid	None.
Nitric acid	0.024
Chlorine	0.30
Total solids	46.40

Hardness { Temporary, 34.40. Permanent, 6.60. Total, 41.00.

(Information furnished by J. Wilson, jr., trustee waterworks board.)

Wellington, Ohio.—The village of Wellington has not been successful in obtaining an adequate supply from wells, although several borings have been sunk in that vicinity to depths of 500 to 1,000 feet. The drift, about 100 feet in depth, furnishes only weak wells. The only recourse for public supply appears to be that of impounding water.

Wellsville, Ohio.—The cities of Wellsville and East Liverpool obtain most of their water supply by pumping from the Ohio River, there being only a few wells and cisterns. Wells are obtained usually at a depth of 35 to 45 feet, except on the higher parts of the bottom land, where a depth of 60 to 70 feet or more is necessary to reach the level of the river. (Information furnished by O. C. Sinclair, mayor.)

West Union, Ohio.—This town is situated upon a high hill, around the margin of which numerous springs of hard water issue, which are utilized by the residents. Wells are 10 to 30 feet in depth and obtain water in the limestone. A good well is estimated to have an average capacity of 20 barrels per day. (Information furnished by J. H. Connor, postmaster.)

Wilmington, Ohio.—Two classes of wells are in use in this city—open wells sunk to a depth of 20 or 30 feet, and bored or drilled wells with a depth of 60 to 100 feet. Some of the latter class of wells overflow. The water is obtained from sand or gravel near the base of the glacial drift or at slight depth in the underlying limestone.

Wooster, Ohio.—Several sources of water supply are in use, and the public supply is from two distinct sources. One reservoir is filled by pumping water impounded from a small stream; another is filled from a large well. The private wells are of two classes—open wells dug to a depth of 14 to 20 feet, and drilled wells with a

depth of 80 to 140 feet. The following sanitary analysis is from a sample taken from the pond used to fill one reservoir:

	Parts in 100,000.
Free ammonia	0.013
Albuminoid ammonia	0.036
Nitrates	None.
Nitrites	None.
Chlorine	0.71
Sulphureted hydrogen	None.

Turbidity, very marked.
Color, yellowish.
Taste and odor, slight.

Other analyses have been made which vary somewhat from the above, but copies are not at hand. (Information furnished by C. E. Thorn.)

Xenia, Ohio.—The public water supply since 1887 has been from a series of springs located on the borders of the city. These for some years yielded about 1,000,000 gallons per day, but in the drought of 1894 and 1895 their flow became reduced to one-tenth that amount. Prospect borings for water near the springs failed to develop any adequate supply. The private wells are of various depths, ranging from 10 to 80 feet. They are largely obtained in gravel near the base of the glacial drift. In some cases they are liable to contamination because of insufficient cover. The need of a more adequate public supply is very great.

Youngstown, Ohio.—The city obtains its public supply by pumping from the Mahoning River. For high service a standpipe is used, but for low service direct pressure. Many wells have been drilled in the vicinity of this city which obtain a slightly brackish water, unpleasant for drinking. Shallow wells on the uplands often obtain a good quality of water at convenient depths. Those in the valley are in many cases liable to contamination, and their use is largely discontinued. (Information furnished by W. S. Hamilton, superintendent of waterworks.)

Zanesville, Ohio.—The public supply is pumped from the Muskingum River to a reservoir on the bluffs. An analysis of the water is given in the tables. Many private wells are in use, which usually obtain water in gravel or sand. The Artificial Ice Company obtains a supply from a well 66 feet in depth. An analysis of its water appears in the tables.

RAINFALL.

At the close of the year 1895 the State weather service of Indiana maintained twenty-six points of observation of precipitation, so distributed as to represent fairly well all parts of the State. The following summary of available records, prepared under the direction of Prof. H. A. Huston, director of the State weather service, appeared in his monthly report for December, 1895. It includes, with the observations for the State weather service, all the reliable records published prior to the organization of that service.

It will be observed that the normal annual precipitation for the State for an average period of fourteen years is 39.57 inches, and that there is a steady decrease from south to north in the amount of precipitation, there being in the southern part 43.57 inches, in the central part 38.15 inches, while in the northern part there is but 35.49 inches. This decrease in amount of rainfall from south to north affects the neigh-

boring States on the west (Illinois and Iowa) and extends northward beyond the national boundary. As shown below, it is not so perceptible in Ohio.

Table of precipitation in Indiana.

[From report of director of State weather service, 1895.]

Place of observation.	Number of years.	Normal.	Greatest annual amount.	Year.	Least annual amount.	Year.
		Inches.	*Inches.*		*Inches.*	
Mount Vernon	8	44.91	57.15	1890	36.09	1894
Princeton	12	39.56	56.96	1890	27.95	1887
Marengo	13	64.20	97.38	1890	44.29	1886
Vevay	30	44.52	60.33	1883	26.53	1895
Butlerville	10	43.41	52.69	1890	32.72	1895
Worthington	13	42.21	54.78	1883	32.73	1895
Seymour	8	41.97	49.88	1890	33.43	1894
Columbus	12	37.77	46.07	1890	27.08	1894
Madison	2	37.86	40.16	1894	35.54	1895
Terre Haute	2	30.01	32.70	1895	29.32	1894
Cambridge City	3	36.57	47.87	1893	28.41	1895
Huntington	2	26.22	27.61	1894	24.83	1895
Valparaiso	3	33.04	35.67	1894	30.42	1895
Kokomo	3	31.33	36.15	1893	27.42	1894
Marion	10	31.02	36.60	1893	22.61	1895
Jeffersonville	7	43.05	58.33	1890	36.86	1895
Connersville	13	39.09	50.99	1890	23.68	1895
Indianapolis	24	44.16	57.33	1876	34.13	1894
Mauzy	15	41.10	57.31	1888	27.05	1895
Logansport	11	38.17	43.62	1885	25.97	1895
Rockville	8	37.09	43.58	1890	29.53	1894
Farmland	13	39.63	51.21	1890	28.47	1894
Lafayette	16	38.05	47.21	1882	27.01	1895
Delphi	10	36.83	49.98	1890	26.23	1895
Columbia City	10	35.50	42.34	1890	26.26	1895
Angola	11	36.57	42.20	1890	31.06	1894
Northern portion	12	35.49	43.77	1892	26.60	1895
Central portion	12	38.15	47.05	1890	29.38	1895
Southern portion	12	43.57	60.10	1890	35.61	1894
State	14	39.57	50.86	1883	30.99	1895

In Ohio at the close of 1895 nearly one hundred and fifty independent observers sent in reports to the State climate and crop service. About one-third of these stations have maintained systematic observations for an average period of eleven years, the length of period varying from five years to twenty-five at the different stations. The normal

annual precipitation for the State for the thirteen years prior to 1896 is 37.87, or 1.7 inches less than in Indiana. The average of greatest annual precipitation for the stations is 42.65 inches, and the average of least precipitation is 31.02 inches, thus giving a range of 11.63 inches in the amount of annual precipitation. The greatest annual precipitation noted at any station is 65.39—at Demos, in Belmont County, in the year 1890. The least annual precipitation noted at any station is 20.50 inches—at Celina, in Mercer County, in 1895.

The following table, taken from the report of the director of the Ohio section of the Weather Bureau for 1895, illustrates the above statements and presents the normal rainfall, the range in rainfall, and years of record for each station where observations have been long maintained. It will be observed that the northern section has on the whole a decidedly lower normal rainfall than the middle and southern sections. But certain stations, such as Canton, Hiram, and Garrettsville, have a rainfall much above the normal for the State. The cause for such exceptionally high rainfall is not apparent, nor is the low rainfall at Dayton, Celina, and Springboro.

Table of precipitation in Ohio.

[From report of director of State climate and crop service, 1895.]

Place of observation.	Number of years.	Normal.	Greatest annual amount.	Year.	Least annual amount.	Year.
Southern section.		*Inches.*	*Inches.*		*Inches.*	
Athens	6	37.80	49.10	1890	32.86	1894
Cincinnati	25	39.23	54.67	1880	26.59	1894
Circleville	5	33.18	39.57	1888	26.40	1895
Clarksville	9	39.00	47.70	1893	31.88	1889
Dayton	13	35.77	46.97	1883	26.78	1889
Hanging Rock	13	41.99	60.22	1890	32.52	1895
Logan	12	42.65	58.69	1890	32.69	1895
Marietta	13	41.28	60.99	1890	26.61	1895
McConnellsville	12	39.14	54.22	1890	29.35	1895
Portsmouth	11	41.54	56.08	1890	31.24	1895
Springboro	5	34.14	45.92	1890	25.95	1895
Waverly	12	38.69	53.58	1890	25.26	1895
Waynesville	7	39.50	48.28	1893	28.27	1895
Middle section.						
Celina	8	32.41	41.67	1890	20.58	1895
Columbus	17	39.28	51.30	1882	28.50	1889
Demos	6	38.03	65.39	1890	27.85	1894
Greenville	10	36.58	43.71	1888	22.03	1894
Kenton	7	38.59	50.65	1890	26.10	1895

Table of precipitation in Ohio—Continued.

[From report of director of State climate and crop service, 1895.]

Place of observation.	Number of years.	Normal.	Greatest annual amount.	Year.	Least annual amount.	Year.
Middle section—Cont'd.		*Inches.*	*Inches.*		*Inches.*	
New Alexandria	11	41.89	58.53	1890	31.95	1887
New Comerstown	10	41.04	62.79	1890	28.67	1895
North Lewisburg	13	40.15	49.50	1893	28.95	1895
Ohio State University	13	37.26	50.47	1890	26.95	1895
Westerville	10	37.96	49.24	1890	28.80	1895
Northern section.						
Akron	9	37.95	53.09	1890	31.05	1894
Ashland	7	35.90	49.00	1890	26.97	1894
Canton	12	39.30	54.52	1890	31.29	1894
Cleveland (W. B.)	24	36.56	51.51	1878	27.09	1895
Cleveland (Hyde)	13	37.30	49.35	1890	29.73	1895
Ellsworth	5	32.66	37.45	1888	28.18	1895
Findlay	6	36.56	42.75	1890	29.28	1894
Garrettsville	7	40.03	53.81	1890	33.86	1895
Gratiot	6	39.04	57.52	1890	28.69	1894
Hiram	13	40.49	51.33	1890	30.34	1886
Lordstown	6	34.80	49.43	1890	28.72	1895
Oberlin	13	33.27	45.91	1890	25.01	1894
Orangeville	5	34.33	46.36	1890	24.97	1894
Sandusky	18	34.75	46.37	1881	24.89	1889
Tiffin	7	33.65	45.57	1890	27.27	1889
Toledo	25	31.02	45.91	1881	21.33	1894
Upper Sandusky	12	36.74	48.03	1890	31.67	1886
Wauseon	23	36.86	52.55	1892	28.49	1888
Wooster	11	34.49	54.21	1890	31.32	1894
Youngstown	11	33.52	50.93	1890	26.20	1887
Southern section	13	38.53	.....	.....	.....	.....
Middle section	10.5	38.32	.....	.....	.....	.....
Northern section	12	35.96	.....	.....	.....	.....
State	.....	37.87	.....	.....	.....	.....

There is a sufficient amount of precipitation, and the precipitation is so well distributed throughout the year, both in Indiana and Ohio, that droughts of disastrous effect are rare. Usually the soil is sufficiently pervious to absorb a large portion of the precipitation and yield it at the needed times to the growing crops. There are, however, portions of both States where a compact white clay soil prevents the absorption

of moisture. In such localities the surface also is usually very level and the tracts are poorly drained. As a consequence the land is flooded in rainy seasons and baked in seasons of drought. The portion of Indiana most seriously affected in this way lies outside the limits of the newer drift, in the southeastern corner of the State. It embraces southwestern Franklin, southeastern Decatur, Jennings, Ripley, Dearborn, and Jefferson counties, and the water partings in Ohio and Switzerland counties. A smaller district is found on the western border of the State in Clay, Vigo, and Sullivan counties. In Ohio the most extensive district is found in Clermont, Brown, Clinton, and portions of border counties in the southern part of the State. The problem of opening these soils and rendering them permeable to moisture and air is one of great agricultural importance.

There are small areas where the soil allows the water to pass downward beyond the extent of vegetation. Such are the gravel and sand plains which border many of the valleys in the northern and western parts of Indiana and the southern part of Ohio. The situation of these tracts is usually favorable for irrigation, as they are found on the lowlands. It is thought that by the use of irrigation in seasons of drought the value of such lands may be greatly increased, and that the returns will more than meet the expense.

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